The CONSTRUCTION OF VITRIFIED BRICK PAVEMENTS

Including Recommended Specifications

Mika Jochen 1986

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Including

Recommended Specifications

National Paving Brick Manufacturers Association
CLEVELAND ∴ ∴ ∴ ∴ OHIO

"No expenditure of public money contributes so much to the national wealth as for building good roads."

—President Calvin Coolidge in his annual message to the 68th Congress, Dec. 6, 1923

FOREWORD

In publishing this book on Brick Pavement Construction together with Recommended Specifications, the National Paving Brick Manufacturers Association presents to the student of highway engineering and to the practicing engineer the results of many years of study and observation of the behavior of vitrified brick pavements under varying traffic conditions and climatic influences in all sections of the country.

Effort has been made to include everything that will suggest progress in design and construction. Advantage has been taken of the most recent discoveries in the science and art of road building that will add to the service value and durability of brick paved streets and roads.

The contents of this book are specific wherever possible, but the sound judgment of the engineer must be exercised in applying them universally. It is not modern highway engineering to draw uniform specifications applicable to every street in a city, or to stand at one end of a five mile stretch of road to be improved and draw uniform specifications to cover the entire job. It is conceivable that the design might wisely be altered half a dozen times or more on as many different streets or as many miles of highway.

We are publishing this book in the hope that it will serve engineers in the preparation of their specifications, aid students of highway engineering in developing their judgment, and be an encouragement always for better design and construction of brick pavements. The recommended specifications contained herein are so designed that they may be used bodily by the profession and, as with previous editions, engineers are welcome to them in their entirety.

NATIONAL PAVING BRICK MANUFACTURERS ASSOCIATION.

Cleveland, Ohio,
January, 1924.

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CHAPTER I

INTRODUCTION

Any single phase of study in the highway engineering field is given more time, more thought and more serious consideration today by the student and the practicing engineer, than was given to the whole subject a generation ago. It is right that this is so, because there is no public or private undertaking today in the whole range of engineering science that is of wider interest or of greater potential economic value to our country than road building.

The amount of money that is annually invested in the construction and maintenance of our city streets and country highways is staggering and counted in tens, yes, hundreds of millions of dollars. It is only natural that in this vast expenditure there is some waste in time, in effort and in money. Ill-considered plans, faulty designs and inferior materials all play their part, and yet it can be said truthfully that the sincere, earnest and conscientious effort and scientific research of the highway engineers of the country, technical societies and trade associations are fast eliminating these mistakes and the science of street and road building is becoming each day more exact. As time, experience, technical study and observations establish new truths, these will be taken advantage of to the mutual benefit and satisfaction of the producer of the materials, the engineer who designs and supervises the work, the contractor who does the physical construction, and the consumer who uses and pays for the improvement.

Vitrified brick pavements have been built and used as such for many generations in foreign countries, notably in Holland, and have since 1871 been serving on the city streets and country highways of our own country in ever increasing mileage. Their construction has developed and improved in this more than half a century to keep pace with the changing form and intensity of our traffic. The type of construction recommended a generation ago is now not generally adapted to our traffic. The industry constantly is watching and studying to improve the material as individual units and to perfect their collective use in pavements; forecasting to the extent of human ability the probable nature and intensity of the traffic a generation or more in the future, recommending and specifying construction accordingly.

The construction of vitrified brick pavements presents no new or mysterious problems; no elaborate equipment is required, and no unusually or specially trained technical men are necessary for the actual physical operation.

The outline that follows, brief as it may be, should be sufficiently inclusive, and the supplemental specifications sufficiently specific, to give the student of highway engineering or the practicing engineer who has had some fundamental training in the general subject of highway

DEFYING OLD AGE IN HOLLAND

Nebuchadnezzar and his father laid brick pavements with asphalt filler on the streets of Babylon. Napoleon laid brick pavements on roads in Holland. This latter country boasts today of brick pavements more than a century old and still giving service.

engineering, a definite picture of the particular features involved in the design and construction of vitrified brick pavements.

The paving brick industry was the first to answer the call of Herbert Hoover, Secretary of Commerce of the United States, for the "Elimination of Waste" in American industry by means of the simplification of varieties and standards and the elimination of excess types and sizes.

In November, 1921, Mr. Hoover afforded the opportunity for the joint consideration of the possible elimination of excess types and sizes of vitrified paving brick by representative national engineering organizations, government departments including the Bureau of Public Roads, and the paving brick manufacturers.

The premise on which the work was undertaken by all interested parties was that the manufacturer is in the position of being compelled to manufacture the type and size of brick called for by the engineer and that, therefore, simplification would have to start with the engineer, or at least could not be brought about successfully without the engineer's leading the way.

At the time of the first meeting in November, 1921, it was found that there was a total of 66 types and sizes of vitrified paving brick being manufactured throughout the country. Carefully considered reductions at that and two subsequent annual meetings of the "Permanent Committee on Simplification of Variety and Standards for Vitrified Paving Brick of the Department of Commerce of the United States" have been so numerous that when this permanent committee meets in March, 1924, to consider further eliminations, it will be able to center its attention on not more than six.

The permanent committee will hold regular meetings to further the simplification movement in this industry until such time as only those types and sizes remain which are found necessary to provide vitrified paving brick of the utmost serviceability to the public for every paving need.

CHAPTER II

Underdrainage and Elimination of Water

The first subject to be considered in any book on highway construction, the first thoughts of the engineer in designing his pavement, and the first phase of the physical construction of the street or road, is that of underdrainage and elimination of water. It is well that this is first

DOES DRAINAGE PAY?

Illustrating the effect of underdrainage as well as the lack of it. Adequate provision for underdrainage is made in the section in the foreground. No provision for underdrainage was made in the section back of the line A-A.

Note that while the surface of the pavement over the undrained section is heaved up due to uneven sub-soil support, the brick themselves are practically undamaged.

as no phase of highway engineering deserves or requires more attention. More otherwise excellently designed and carefully built pavements have been ruined by lack of sub-soil drainage and the proper

elimination of water from the subgrade than from any other single cause.

As it is generally understood, underdrainage is a provision for relieving the subgrade of water and moisture. To do this is a worthy accomplishment, but relieving the subgrade of water after it has been allowed to enter is not the first consideration. Exclusion of water from the subgrade structure is and should be the end sought.

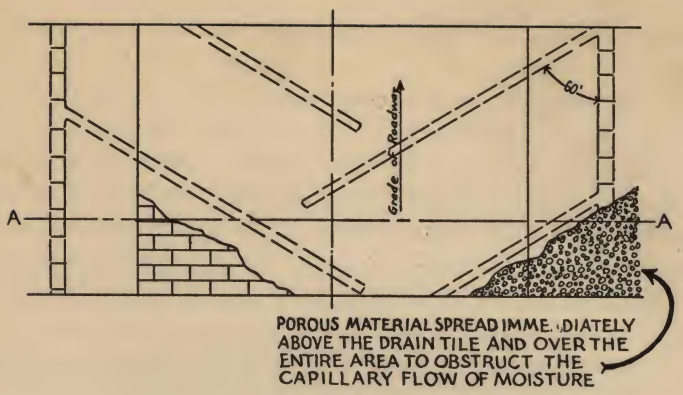
Important as this subject is, it is not possible to definitely prescribe the remedy for this problem in general terms or in general

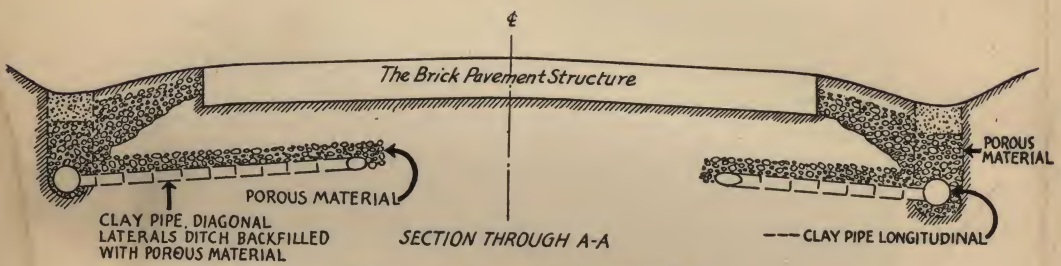
WHEN NATURE DRAINS

Another view of the same road shown in the previous illustration, this section being over a soil that provided excellent natural drainage. This section has borne the same traffic under the same climatic conditions as the other and still the surface is unaffected. Dry soils are capable of supporting the heaviest of traffic loads; saturated soils can support no load worthy of the name.

specifications suited to every condition. Each street and each highway is a separate study throughout its entire length. Soil and drainage conditions vary on practically every project and, more often than not, on different sections of the same project.

The engineer, therefore, should carefully examine the proposed location of the roadway, noting all evidence of underground flow or seepage, study the topography of the surrounding country for the action of rainfall on the roadway right of way in different seasons of

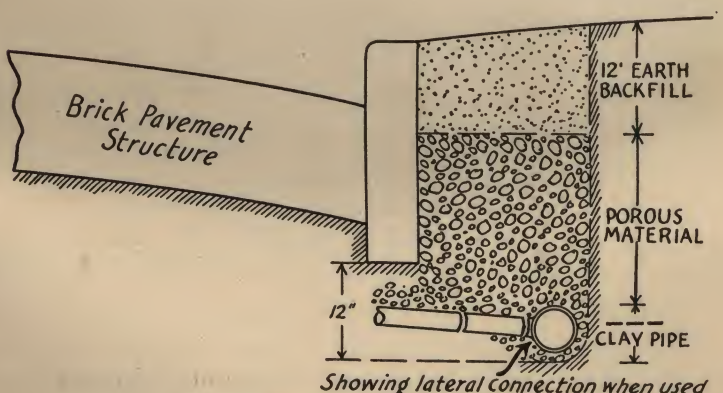




DRAINAGE IS FIRST CONSIDERATION

A suggested treatment for the most aggravated cases of saturated sub-grade. Such a system takes care of all requirements ranging between what water could be disposed of through a line of longitudinal pipe on one side of the roadway to the double herring-bone system sketched above.

Disposal of water away from the roadway should be made as frequently as possible According to grades, inlets may be placed at intervals through which surface water may enter the underground disposal pipe. Thus the need for deep side ditches is removed and the danger of sub-soil softening by rainfall is greatly reduced.



Showing lateral connection when used

FOR CITY STREETS

The method shown above for under-draining a city street may be amplified according to the methods and under the conditions described in the first sketch.

the year, and if the effects therefrom will render the subgrade in its present condition an uncertain support at any time, he should prepare special plans to prevent, if possible, this water from entering the subgrade.

This being impossible, his efforts should be devoted to planning a rapid removal of the water, even to underlaying the entire pavement structure with broken stone, if necessary, where the capillary attraction is pronounced.

It will be appreciated, therefore, that any drainage provision necessarily becomes a matter of the engineer's judgment, based on his knowledge of the soils with which he is dealing and the surrounding topographical conditions available for water disposal.

It is fully recognized that a stable sub-soil affords a greater measure of support to the pavement than an unstable one. It is apparent that well drained subgrades make possible the more economical construction of artificial bases as well as permit a choice of base from more general types. Such, for instance, are possible economies in concrete bases and the building of the rolled types of bases of gravel, stone or slag.

Sewer provisions for water disposal in towns and cities are generally so ample that but little additional drainage is required to keep the subgrade dry and permit it to render its maximum bearing value. What little is needed, however, should not be overlooked.

Open ditches along the side of our country roads are the usual reliance for their drainage, but they are not always dependable nor are they always the least expensive. They usually are a menace to present day travel and expensive to maintain.

Tile underdrains placed along the side of the road, with the trench back filled with a coarse material, will intersect the horizontal underground flow of water from adjacent areas. They function winter and summer, are not subject to constant expense and are equally efficient for carrying away the surface water from rain falls.

In aggravated cases, lateral underdrains placed under the pavement and connected to the main drains are often used and recommended to more thoroughly and completely eliminate the water from the subgrade.

Recommended Specifications
Underdrainage and Elimination of Water

LOCATION: Tile and broken stone drains shall be provided of such size and in such location as shown on the plans for the improvement accompanying these specifications.

QUALITY: The drain tile or vitrified pipe as called for on the plans shall be hard burned to insure against disintegration or crumbling, reasonably smooth on the

inside and free from cracks, warps and imperfections that would appreciably decrease its strength or service.

SIZE: The minimum length of such pipe shall be twelve (12″) inches and minimum diameter four (4″) inches.

TILE OR PIPE DRAINS: The tile or pipe shall be laid true to line and grade with close joints and shall rest on a solid bed throughout its length. The tile or pipe shall be covered as laid with gravel, broken stone or crushed slag, placed around and above it to a height of at least one foot above the tile or pipe. The back fill above the stone, gravel or slag filling shall be of suitable earth tamped in place in layers not exceeding four (4″) inches in thickness.

Lateral and surface connections shall be made with suitable specials. The drains shall have suitable and frequent inlets and outlets designed and protected as shown on plans.

STONE DRAINS: In stone drains the trench shall be excavated to the dimensions shown on the plans, finished to the given line and grade and be uniform in surface and tamped if necessary. The bottom course, from eight (8″) inches to ten (10″) inches in depth, shall be of sound, hard and durable stone, gravel or slag varying in size from that which will pass through a revolving screen having holes two and one-half (2½″) inches in diameter to that which will pass through a revolving screen having holes five (5″) inches in diameter. It shall be placed so as to give maximum voids.

The top course of stone, slag or gravel, all of which will pass through a screen having holes from three-fourths (¾″) inch to two and one-half (2½″) inches in diameter shall then be placed over the bottom course to fill the trench to a total depth of at least twelve (12) inches.

Above this the earth filling shall be placed as heretofore specified and suitable outlets provided.

STONE UNDERBEDDING OR SUB-BASE: Where the plans call for a layer or course of broken stone, gravel or slag to be spread under the entire area of the road for acceleration of drainage and to prevent water entering the upper structure of the road, the stone or other material shall be sufficiently large and uneven to contain air volume that will prevent capillary movement of moisture. Sufficient fine material shall be overlaid to prevent filtration of any superstructure material, artificially placed over it. This layer shall be thoroughly compacted before any superstructure material is placed upon it.

CHAPTER III

Grading

Artistic as well as scientific judgment is brought to play in grading a roadway preparatory to paving. The artistic sense forbids straightening out every little curve and shaving each slight grade to a monotonous level. On the other hand scientific judgment often advises the elimination wholly or partially of dangerous curves and overly steep grades. From an economic point of view and where it is practical to do so, all grades should be reduced, or the highway so located, to give a maximum grade of not exceeding eight or ten per cent.

After plans and specifications are drawn and the drainage features provided for, the next step is to grade the roadway and approaches so that when repeatedly rolled and thoroughly compacted, the finished surface of the subgrade conforms to the grade specified.

All vegetable matter, soft, spongy earth, muck or quicksand which will not compact under the roller should be removed and replaced with material which can be compacted.

Where filling is necessary the earth should be applied in layers of not to exceed twelve inches in depth and each layer should be repeatedly rolled and thoroughly compacted before successive layers are applied. Often, where the fill is of unusual depth, it is found advisable to allow it to settle, perhaps through a winter or rainy season, before completing the pavement. On heavily traveled routes, temporary surfaces of cinders, stone or other material may be applied so that traffic need not be greatly interfered with because of the unfinished portion. As in excavations, so in embankments, all material that will not compact thoroughly should be excluded.

A self-propelling three wheel type of roller weighing not to exceed ten tons is most satisfactory for compacting the subgrade. It cannot be too strongly emphasized that the rolling must be repeated until the compaction is thorough and uniform. Depressions created by rolling should be brought to subgrade with additional material, the rolling repeated, and this performance continued until the subgrade is of uniform density, smooth, even of surface, and true to grade.

During the grading care should be taken to prevent earth from being deposited upon any material, brick, stone, sand, or gravel, which may

GRADING THE HIGHWAY

Using tractors as the motive power served to speed up the grading on this job. Obviously no argument is needed to support the use of modern machinery in street and highway construction.

ROLLING THE SUB-GRADE

Repeated rolling of the sub-grade until it is thoroughly and uniformly compacted is of the utmost importance. Upon the uniformity of the sub-grade, brought about by drainage, and thorough compaction, depends to a great extent the continued perfect alignment of the pavement surface.

be piled along the side of the road to be used later in the pavement proper, because absolutely clean materials are a requisite for proper construction of a lasting base and surface.

The relative merits of crowned or flat subgrades have frequently been discussed at length by prominent engineers. The best practice today, however, indicates a distinct preference for a crowned subgrade of the same contour as the surface of the finished pavement. The crown to be established for a vitrified brick pavement depends largely on the location of the street or road, the type of its design, the longitudinal grade of the pavement, the width of the walks, street car tracks, etc., and the topography of the surrounding country. Generally speaking the crown should be such that the transverse slope of the pavement surface will not exceed three-eighths inch to the foot or be less than one-eighth inch to the foot.

Super-elevation should always be applied to the outer edges of curves on highways, and where practicable on city streets as well.

Upon proper preparation, including adequate drainage, of the subgrade, depends to a large extent the life of the base and surface, therefore this first phase of highway construction, while it may be considered coarser work, requires equally as much and sometimes more care and skill than the remainder of the pavement structure.

Recommended Specifications

Grading

CLEARING AND GRUBBING: All objectionable brush, stumps, fences, boulders, stones or other material, within the limits of, or overhanging the highway shall be removed. All trees, stumps, roots and brush shall be cleared and grubbed from the area to be improved in such a manner that, in case of a fill, no part of them shall be within eighteen (18″) inches of the finished surface of the subgrade; or in the case of an excavation, no part of them shall be within three (3″) inches of the finished surface of the subgrade. All stones that are less than three (3″) inches below the finished surface of the sub-grade also shall be removed.

GRADING: The roadway and approaches to be improved, shall be graded to such lines and cross sections, that, when rolled, the finished surface of the subgrade shall conform to that shown in the plans.

EXCAVATION: All vegetable matter, and soft, spongy earth, muck or quicksand, which will not compact by rolling shall be removed and replaced with material that can be compacted.

EMBANKMENT: Earth in embankment shall be applied in layers not exceeding twelve (12″) inches in depth, and each layer shall be thoroughly rolled and compacted before successive layers are applied. All vegetable matter, and soft, spongy earth, muck or quicksand which will not compact by rolling shall be excluded from embankment as provided for in excavation.

ROLLING: The roller used in compacting the subgrade shall be of the self-propelling three wheel type, weighing not to exceed ten (10) tons. Rolling shall continue until the subgrade is thoroughly compacted. Any depressions in the surface

thereof created by rolling shall be brought to grade by the addition of suitable material. Rolling shall then be repeated until the subgrade is of uniform density, with a smooth and even surface.

PROTECTION OF MATERIALS: No earth from excavation or embankment shall be deposited against or upon any material, brick or stone, sand or gravel to be used in the pavement. Such materials shall be so placed and protected that they will be uninjured by travel or by grading operations.

TESTING: Immediately before the artificial foundation is laid, the surface of the subgrade shall be tested, and if not found as required, it shall be corrected to conform to the true grade shown in plans.

CHAPTER IV

Curbs and Headers

Under this heading are discussed the stone curb and header, the concrete curb and header, the integral brick curb, and the integral concrete curb, such integral curbs, when used, being built monolithic with a concrete base.

Curbs are used on practically all city streets and their use there is a necessity. The height of the curb above the pavement surface generally varies on every street depending on the local topography. Generally speaking this height is from five to seven inches when both curbs are at the same elevation. Pavements built on the side of a hill, or pavements built in extremely level country where it is hard to provide adequate grade for surface drainage, of course require special study and design to determine the most economical and practical height.

A practice which might be termed "progressive paving" has developed in recent years whereby base courses are laid and opened to traffic for longer or shorter periods before a surface is applied. In some instances engineers lay concrete bases with a well-finished surface and expect it to serve as a pavement for several years until such time as city finances permit a finished job. Anticipating a brick surface, they provide for city streets a curb of about ten inches. Thus, when the bedding course and brick are laid several years later a curb of about six inches, a desirable and customary depth, remains.

Many of our country highways are built with curb flush with the top of the pavement and either placed prior to the construction of the base course or built integrally with it in the case of concrete bases. While this might be said to be the prevailing practice today, there is a growing tendency to eliminate these curbs. Many of the engineers using the edging curb feel that this is necessary to hold the brick and bedding course in place and that the edging furnishes for the driver a definite boundary to the pavement that is of value, particularly at night.

Practice and experience of many years has proved that with either asphalt or cement grout filler there is no need for a curbing to hold the brick in place after the filler is applied. A form of wood or steel is

necessary while the bedding course and brick are being laid, and often this two by four inch wooden form is left in place after the pavement is completed. Shoulders of broken stone, gravel or slag from one to two feet in width and extending in depth to the bottom of the base course, thoroughly compacted and rolled and often, on heavy traveled and congested highways, bound with a penetration of asphalt or tar, are taking the place of the edging curb.

Not only is the expense of the edging curb eliminated, but its absence provides just that much additional width of highway on each

ROLLED STONE SHOULDERS

There is no real need of curbing on the brick paved country highway if the shoulders are properly maintained. The accompanying photograph illustrates how these shoulders and the brick surface are rolled at the same time. In some instances the shoulders are bituminous bound.

side of the pavement proper and, what is most important, it eliminates the troublesome and destructive action that follows when surface water sooner or later gets between the brick and the edging curb and either collects in and saturates the bedding course or gets into the subgrade, instead of flowing freely off the pavement into the drainage ditches as it should. Care and attention should be given to the maintenance of these shoulders, however, to prevent ruts being formed that will allow water to gather and penetrate into the base or subgrade.

Likewise, and for much the same reasons, the use of the cement concrete combined curb and gutter is fast losing favor among city engineers and is not recommended, as not only does this construction permit water to sooner or later get into the pavement substructure at

the junction of the pavement and gutter, but the action of the traffic on this joint soon causes a rut to be formed and necessitates the repair or replacement of the concrete gutter.

There is a psychological, as well as utilitarian reason behind the practice, which has developed within the last few years, of using integral brick curbs on brick pavements. A strip of stone or concrete flush curbing down each side of a pavement has a tendency to confine traffic. In fact, a motorist seems to develop the habit of staying several feet inside of the inside edge of such a curb unless it is absolutely necessary for him to "get over."

Where a brick surface extends entirely across the road and is met at each side by a well maintained rolled stone shoulder, sometimes bituminous bound, the motorist seems to be more inclined to stay over on his side of the road, thereby utilizing the entire width of the paved surface.

While the practice of curbing country highways is considered wasteful, as previously explained, some engineers still prefer having some sort of edge protection near heavy traffic cities. In such cases, the brick curb, set flush, admirably serves the purpose of a curb and at the same time provides a wider pavement, or at least what amounts to a wider pavement in view of the traits of many motorists.

The base is laid as usual except that the forms are set to line and grade at just the height of the base course. Immediately after the concrete base is prepared, and before the initial set has taken place, a layer of one to one mortar is spread a sufficient distance from the edge of the base course to provide a mortar bed in which to set the brick curbing. Using the brick for the curb with its four inch face as its depth and using brick three inches in depth for the balance of the pavement, ample allowance is provided for a one inch bedding course. In case brick three and a half or four inches in depth are used for the body of the pavement, the mortar bed should be of such thickness that will allow the bedding course to be at least one half an inch in depth on the inner edge of the curb where it joins the pavement proper, the surface of the brick pavement in either event being brought even with the surface of the brick curb.

In some instances the brick are laid crosswise as headers, forming a curb eight and one-half inches wide, while in other cases they are laid lengthwise, forming a curb three or three and one-half inches wide, depending on the type of brick used. The design with the brick laid as headers is preferable. The one to one mortar is used to fill and seal the joints in the curb, the balance of the pavement being asphalt filled.

Curbing of sandstone, limestone or granite when specified should be of the best quality, homogeneous and free from seams, cracks and other

WOODEN FORMS

How wooden forms are laid to grade and securely staked in position before pouring the concrete

STEEL FORMS

Illustrating the use of steel forms for the construction of the integral concrete curb. These forms also act as guide rails for the template shown in the background.

defects. The depth of the curbing depends on the local conditions and available supply of stone. It is seldom less than eighteen inches and should never be less than twelve inches in depth by four inches in width. The length will vary between six and eight feet. The upper surface should be finished to a uniform width and the pavement side

INTEGRAL BRICK CURB

Illustrating one of the methods of laying the integral brick curb. A cement mortar is used in laying the curb, asphalt filler being used for the balance of the pavement.

faced to a depth sufficient to reach the foundation. The ends are dressed at right angles to the upper surface and to the same depth required for the face. Joints between the stones should not exceed one-quarter of an inch for a distance of twelve inches from the top. The ends of circular curbing should be cut radially.

Prior to completion of the fine grading the curb is set true to line and grade. Stone headers when used at the ends of pavements and at intersecting roadways must be of the specified width and depth as shown on the plans and specifications, and are usually of the same quality as that specified for curb, although generally of less depth and length.

The dimensions of concrete curbs and headers conform in general to those of stone. Forms for the concrete are set true to such lines and grades that the finished curb may conform to the plans. Stakes and clamps are used to hold the forms together and in place. Care should be taken to see that the forms do not deflect from the true position more than one-fourth inch.

To prevent concrete sticking to the forms, and to facilitate easy removal of the forms without disturbing the concrete, the inside of the forms should be oiled with mineral oil prior to concreting.

Concrete for curbing is generally mixed in proportions of one part cement, two parts fine aggregate, and four parts coarse aggregate and is seldom made stronger than a one-one and a half-three proportion.

FINISHING THE CURB

This illustration shows how one man following behind the mixer, puts the finishing touches on the integral concrete curb.

The coarse aggregate should be of such maximum size that all will pass three-quarter inch circular openings in a revolving screen. After being thoroughly mixed the batch is deposited in the forms and carefully spaded and settled to insure a uniform contact of the mortar with the forms. A film of mortar should be flushed to the surface in this operation thus permitting the upper face to be finished smooth and even.

When the concrete has sufficiently set, the forms may be removed and the curb finished by hand to smooth out any roughened condition,

the upper inside edge being finished to a radius of one and one-half inches. After a sufficient time has elapsed to prevent any injury to the surface, it should be covered and kept wet for a period of not less than five days, especially when weather conditions are such as to cause rapid drying. The same operation is followed in constructing the concrete header except that the upper inside edge need not be finished to a radius as is the curb.

Where an integral concrete curb is desired, it is built of the same material and at the same time as the concrete base. The forms, either of wood or metal, are handled as previously described. Construction of the integral curb and base proceed simultaneously.

In special cases a galvanized steel armor is used to protect the edge of the curb.

Recommended Specifications
Stone Curb and Header

QUALITY, SIZE AND FINISH: The curbing shall be of the best quality sandstone, limestone or granite as indicated on the plan and bidding form, homogeneous and free from cracks, seams and other defects, and shall not be more than eight (8) feet or less than four (4) feet in length. The stone shall be —— (—) inches in width on the top after dressing, not less than —— (—) inches in depth, and not less than the same width on the base as is specified for the top.

The stone shall be dressed at least ten (10) inches down on the face and ends and three (3) inches down on the back.

Radial curb shall be not less than five (5) feet in length, conforming to the dimensions and dressed as for straight curb to the radius shown on the plans, and with the ends cut radially.

The joints shall not exceed one-quarter (¼″) inch for a distance of twelve (12″) inches from the top, but may be wider from this point to the bottom.

SETTING: The curbing shall be set on edge to the line and grade given, prior to the completion of the grading. Both the bed and the backing shall be thoroughly tamped with heavy tampers to the full depth of the stone.

HEADERS: Headers when shown on the plans at the ends of the pavement or at intersections with unpaved streets, or at intersections with streets paved with a dissimilar material, shall be set to the grade of the pavement surface. Stone for this purpose shall have a minimum width of four (4″) inches, a depth sufficient to extend to the bottom of the base course and shall be not less than three (3″) feet in length.

Recommended Specifications
Concrete Curb and Header

FORMS: Forms either of metal or wood for concrete curbing shall be set true to such lines and grades that the finished curb shall conform to the lines and grades given on the plans. Forms shall be held securely in position by means of stakes and clamps so that when filled with concrete, they shall not deflect from the true position more than a one-quarter (¼″) inch.

OILING: The inside face of curb forms shall be oiled with mineral oil prior to depositing the concrete.

SIZE: The curbing shall be constructed in uniform lengths of ten (10) feet, except where shorter sections are necessary for closures, but no section shall be less than four (4) feet. These sections shall be separated by sheet steel templets one-eighth (⅛″) inch in thickness, perpendicular to the face and top of the curbing and not less

than two inches longer than the depth of the curbing. These templets shall be removed from the forms when the concrete has set sufficiently to hold its shape.

The finished width of the curb at the top shall be ——— (—″) inches, the depth ——— (—″) inches and the width at the base one (1″) inch greater than the top.

MATERIALS AND MIXING: The concrete for the curb shall be composed of materials and be mixed as specified for Concrete Base Course except that the coarse aggregate shall be of such maximum size that all will pass three-quarter (¾″) inch circular openings in a revolving screen. It shall be thoroughly mixed in the proportions of one (1) part cement, two (2) parts fine aggregate and four (4) parts coarse aggregate. Concrete shall be deposited in the forms, thoroughly spaded and settled to insure a uniform contact of mortar with the forms, with a film of mortar flushed to the surface. The upper face of the curb shall then be finished smooth and even. The upper inside edge of the curb shall be finished to a radius of one and one-half (1½″) inches. Upon removing the forms, the exposed portion of the curb shall be finished to make smooth any roughened condition.

PROTECTION: After sufficient time has elapsed to prevent injury to the finished surface, it shall be covered and kept wet for a period of not less than five (5) days when weather conditions are such as to cause rapid surface drying.

HEADERS: Where concrete headers are used at the ends of the pavement and at intersecting roadways, they shall be of the width and depth shown on the plans and specifications. Concrete shall be in the proportions of one (1) part cement, three (3) parts fine aggregate and six (6) parts coarse aggregate.

Recommended Specifications
Integral Brick Curb

MATERIAL: Vitrified paving brick used for integral brick curb shall be of the same quality as those used in the balance of the pavement.

Mortar in which the brick are set and which is used to fill the joints shall be made of one (1) part portland cement to one (1) part fine aggregate, conforming to the requirements for these materials outlined under Artificial Bases—Cement Concrete.

CONSTRUCTING CURB: As the concrete base is constructed, and before the same has been allowed to set, a layer of 1 to 1 mortar shall be spread over the base a sufficient distance from the edge of the base course to provide a mortar bed in which the brick are immediately set and the joints promptly filled with mortar.

The brick shall be laid with its four (4″) inch face as its depth, and unless otherwise specified, they shall be laid crosswise of the pavement as headers.

When the pavement proper is to be constructed of brick three (3″) inches in depth, no appreciable amount of mortar is to be put under the brick, to avoid making the bedding course immediately adjacent to the brick curb more than one (1″) inch in depth.

When the pavement proper is to be constructed of brick three and one-half (3½″) inches or four (4″) inches in depth, the thickness of the mortar bed in which the brick are set should be such as to provide a bedding course at least one-half (½″) inch in depth immediately adjacent to the brick curb.

The surface of the brick pavement proper when constructed is brought even with the surface of the brick curb.

PROTECTION: The same protection must be afforded the integral brick curb as is provided for concrete base after its construction.

Recommended Specifications
Integral Concrete Curb

MATERIAL, SIZE AND MIXING: Integral concrete curb shall be built at the same time, and of the same materials, mixed in similar proportions, as the concrete base, and shall not exceed six (6″) inches in width on the surface.

Cement, coarse aggregate, fine aggregate, water and mixing thereof, shall conform to the specifications for Concrete Base.

FORMS: Forms used to retain the concrete curb shall be of wood or metal. They shall be straight and free from warp or bending. Forms shall be held securely

in position, true to line and grade, by stakes and clamps, with the ends closely joining.

Forms shall not deflect from position more than a one-quarter (¼") inch.

They shall be cleaned thoroughly and oiled with mineral oil immediately before placing concrete against them. They shall be staked and clamped not less than fifty (50) feet in advance of placing concrete. Forms shall remain in place not less than forty-eight (48) hours.

PLACING CONCRETE: Concrete for the curb shall be placed so that curb and base proceed simultaneously. Concrete shall be thoroughly consolidated within the forms for the entire depth of the curb. The exposed top surface of the integral curb shall be given a smooth finish.

PROTECTION: The same protection must be afforded the integral concrete curb as is provided for concrete base after its construction. Integral curb shall be protected so that it shall not be chipped or injured in any way prior to laying the brick.

CHAPTER V

Natural Bases

In the last analysis it is the natural soil that forms the actual foundation for all pavements, and the extent to which additional treatment and structure is needed depends entirely upon the character of the soil and the surrounding topography.

In July we drive over a dry, dusty country road and come to the realization that the soil, in that condition, would support any load that could possibly be placed on four wheels. It would seem at such a time

IN SUNNY AND SANDY FLORIDA

Perfect natural drainage is the rule rather than the exception in most sections of Florida and many miles of brick pavements are laid on the natural soil. The accompanying illustration shows the perfect alignment of one of these pavements after years of use and without any artificial base.

that the only protection needed would be one against the abrasive action of rapidly revolving wheels.

We attempt to traverse the same dirt road in the middle of March and we sink to the axles. The only difference between the firm, hard road of July and the impassable mire of March is the difference in moisture content. This helps us to the realization that moisture, if

NO ARTIFICIAL BASE NEEDED HERE

Laying the brick surface on the natural sandy soil. Many sections of the country, because of the sandy and gravelly character of the soil, find brick pavements giving excellent surface without an artificial base.

not excluded or quickly removed, can be an agency for the utmost damage to pavements.

In some sections of the country, however, the natural soil is of such a porous, yet stable nature that it is admirably suited, after thorough and uniform compaction, as a base course for brick pavements without any assistance from artificial base materials. Sandy and gravelly soils are examples. In the midst of protracted rainy seasons or during open springs after hard winters, such soils offer excellent support simply because the natural drainage is speedy.

On the other hand heavy clay, black gumbo, adobe and other soils of similar character attract moisture rather than aid in its natural disposal, and would call for an artificial base to support the wearing surface.

It is in those communities where the soil is principally an easily and quickly draining sand or gravel that brick pavements have been and

are being built without an artificial base. Pavements so designed and constructed 25 and 30 years ago for the light horse-drawn vehicles and before modern traffic was dreamt of, are carrying today's intense traffic without any sign of weakening. Communities erected on such soils are fortunate in that they can obtain highly satisfactory street and highway paving at a price and with an assurance of reasonable permanency not possible in many other sections where soil conditions may be at the other extreme as regards ease of drainage and moisture content.

The preparation of the natural soil for a base course follows the same routine as described in Chapter III on Grading, except that it is the rule rather than the exception to thoroughly wet the sand or gravel to aid in its uniform compaction. Care must be taken to produce a perfect alignment of the natural base in order to insure the greatest smoothness of the finished brick surface. Whether or not it is necessary to adopt artificial means for confining the sand under the brick surface depends entirely upon local conditions and must be left to the judgment of the engineer. In this consideration much depends upon the natural or artificial grading of the grain sizes.

Recommended Specifications
Natural Base

CLEARING AND GRUBBING: All objectionable brush, stumps, fences, boulders, stones or other material, within the limits of, or overhanging the highway shall be removed. All trees, stumps, roots and brush shall be cleared and grubbed from the area to be improved in such a manner that in case of a fill, no part of them shall be within eighteen (18″) inches of the finished surface of the subgrade; or in the case of an excavation no part of them shall be within six (6″) inches of the finished surface of the subgrade. All stones that are less than six (6″) inches below the finished surface of the base also shall be removed.

GRADING: The roadway and approaches to be improved, shall be graded to such lines and cross sections that, when rolled, the finished surface of the base shall conform to that shown in the plans.

EXCAVATION: All vegetable matter and soft, spongy earth, muck or quicksand which will not compact by rolling shall be removed and replaced with material that can be compacted.

EMBANKMENT: Earth in embankment shall be applied in layers not exceeding twelve (12″) inches in depth, and each layer shall be thoroughly rolled and compacted before successive layers are applied. All vegetable matter, and soft, spongy earth, muck or quicksand which will not compact by rolling shall be excluded from embankment as provided for earth in excavation.

ROLLING: The roller used in compacting the base shall be of the self-propelling three wheel type, weighing not to exceed ten (10) tons. Rolling shall continue until the base course is thoroughly compacted. Prior to and during the rolling the natural base shall be thoroughly wetted to assist in and insure thorough and uniform compaction. Any depressions in the surface thereof created by rolling shall be brought to grade by the addition of suitable material. Rolling and wetting then shall be repeated until the base course is of uniform density with a smooth and even surface.

PROTECTION OF MATERIALS: No earth from excavation or embankment shall be deposited against or upon any material to be used in the pavement. Such materials shall be placed and protected that they will be uninjured by travel or by grading operations.

TESTING: The surface of the natural base shall be brought to the crown shown on the plans and before completion be tested with the template. Any variation from the true grade and cross-section shown on the plans shall be corrected.

CHAPTER VI

Artificial Bases

In the discussion of artificial bases for vitrified brick pavements it is presupposed that the subgrade has been designed and built with such artificial drainage as is required to put and keep it in the most stable condition possible at all times. (For a discussion of drainage, see Chapter II.)

One of the merits possessed by the vitrified brick wearing surface is its adaptability to so many varied conditions and the fact that selecting and obtaining a base course material, where an artificial base is needed, is made easy and simple by the large number of base course materials that have proved satisfactory.

Portland cement concrete, rolled courses of gravel, crushed slag or broken stone, worn concrete pavements, worn macadam pavements and worn gravel pavements are serving satisfactorily today, and have for years, as bases under brick surfaces. No one type of base can or should be prescribed to meet all conditions, but there is no condition that cannot be met with one of the bases listed.

CONCRETE BASE

Portland cement, fine aggregate, coarse aggregate and water are the ingredients for a concrete base. The fine aggregate may be composed of sand, stone screenings or slag screenings; coarse aggregates of broken stone, gravel or crushed slag; combined aggregates of bank-run gravel or crusher-run stone or slag.

Portland cement should conform to the requirements of and be treated in accordance with the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials, Serial Designation C-9-21.

Fine aggregate, which should consist of clean sand, or screenings from hard, durable rock, gravel or slag, should be free from soft, friable material, shale or slate, vegetable or other organic matter. It should not contain clay or silt in excess of five per cent. by weight, else the proper bond will not result. The grain sizes should be uniformly graded, all passing one-fourth inch sieve openings.

Where broken stone is used for coarse aggregate it should be reasonably sound and uniformly graded in sizes between a maximum that will pass a one and one-half inch circular opening in a revolving screen and a minimum that will be retained on one-quarter inch openings. As in the case of fine aggregate, it should not contain any soft, friable material, or vegetable or other organic matter.

If gravel is to compose the coarse aggregate it should meet the same requirements as to soundness, cleanliness and size as broken stone. If crushed slag is to be used it should be of good quality, hard, sound and weigh not less than 1800 pounds per cubic yard. It should meet the

POURING CONCRETE BASE

The long trough, easily swung from one side of the road to the other, enables the concrete to be quickly and evenly distributed as it comes from the mixing drum. Little shoveling or rehandling is necessary with such a machine.

same requirements as to size, uniformity and cleanliness as prescribed for broken stone or gravel.

In the case of a combined aggregate, it should be of such character and quality that the separate ingredients would meet the requirements for the coarse and fine aggregates as described in the foregoing paragraphs. Best engineering practice today approves of a run-of-bank gravel that contains not more than seventy or less than fifty per cent. by volume of fine aggregate. The same is true of run-of-crusher stone or slag.

To obtain the maximum strength of a concrete base care must extend even to the water used in mixing. If water contains oil a film forms

around the particles of aggregate and prevents a perfect bond. If it contains acids it interferes with the proper chemicalization. It also should be free of alkalies or vegetable matter. Undoubtedly the cleaner the aggregate and the more perfectly the voids are filled in concrete for the base, the stronger the slab will be. But, slab strength is not the only object sought to be attained or economy to be effected in base construction for brick pavements.

The concrete does not furnish the only support for the wearing surface. A well drained subgrade is the largest factor in supporting the pavement. Concrete bases, therefore, entirely adequate for the service they must render, often can be built by using near-by supplies of bank-run gravel, for the coarse aggregate. Though such gravel may contain fine material like clay or loam up to eight per cent. by volume, and the resultant mixture may be slightly less dense on account of the different grading of grain sizes, there is always provided an ample safety factor that well justifies the use of this material.

It also must be appreciated that the concrete base is not exposed to the direct action of traffic or directly to some of the damaging natural agencies. These statements apply equally well to the use of run-of-crusher field, or other local stone deposits and also to crushed slag where available for the same purpose. Even soft sandstone can thus be adapted for use.

The consistency at which the concrete is placed has an important bearing on its strength. The best evidence for determining the proper consistency is found in the nature of the green concrete in place and by the slump test of samples taken just as the concrete leaves the mixer.

With any given proportion of the aggregates to cement, the strongest concrete is obtained when the aggregates are uniformly distributed to form a homogeneous mass, coupled with the presence of sufficient water, thoroughly admixed, to hydrate the cement, the whole producing a concrete readily handled and placed.

These requirements prohibit the use of an excess of water which would reduce the adhesion of the cement to the fine aggregate, and in turn of the mortar to the coarse aggregate and which, furthermore, would produce a porous concrete upon the evaporation of the water simultaneous with the hardening of the concrete.

On the other hand, a lack of water is prohibited by the requirement of sufficient water to hydrate the cement, ease of handling and placing and freedom from severe tamping. In individual instances the proper amount of water to be used in mixing depends upon the nature of the aggregates, their relative dampness when they enter the mixer

and the use to be made of the concrete. Thorough dry mixing of the ingredients is essential as well as thorough mixing after the water has been added.

Strict supervision of all the operations and factors involved, coupled with the exercise of sound judgment are essential in obtaining the best results in mixing and placing concrete. In mixing, the ingredients should be measured separately and thoroughly mixed. Sufficient

FEEDING THE MIXER

Piles of fine and coarse aggregate in front of the mixer rapidly disappear when attacked by a gang of workmen with wheelbarrows. Note in the photograph how a curb separates the pavement from the car track area.

water to produce a concrete of the desired consistency should be added. Machinery is almost universally used for this purpose today and the mixing drum should be revolved not less than one minute after all materials are placed in it.

In proportioning the materials for a concrete base it should be borne in mind that the mix for a base course need not be as rich as is the case in many other uses of concrete. One part cement to three parts of fine aggregate and six parts of coarse aggregate is the proportion recommended. In the case of combined aggregate the proportion should be one part cement to seven parts aggregate.

Clean materials, proper proportioning of the materials, thorough mixing and uniformity are four things that can hardly be overemphasized.

PLACING THE CONCRETE BASE

Like many other factors in highway design, it is impossible to specify the thickness of base for general use. If there is any criticism that can justly be made of highway practices in the past, it is that there has been too much general specifying and not enough specific specifying. The tendency has been in some sections to overdesign rather than underdesign the modern vitrified brick pavements. Anyone can overdesign a pavement. The engineer is the man whose training fits him to neither overdesign nor underdesign his structure, but to strike that medium of proper design that is safe, durable and economical and, particularly in alternative types of pavements, to make each design comparable with the other.

Thickness of base depends upon the character of subgrade, kind, weight and intensity of traffic and other obvious considerations. One thing may be said in this connection, however, that might be helpful. It is not modern highway engineering to stand at one end of a five mile stretch of road to be improved and draw uniform specifications to cover the entire job. It is conceivable that the design might have to be altered a half dozen times or more in as many miles of highway or on as many city streets.

In placing the concrete base, either wood or metal forms may be used, in case the curbing is not available for this use. The forms should be straight and free from warp or bend. Care should be taken to stake them securely to line and grade so that they will not deflect more than a quarter of an inch. Ends should be tightly joined.

The depth of the forms generally should equal the total depth of the brick wearing surface, bedding course and concrete base course, thus eliminating the necessity for resetting them for each operation. Wooden forms best adapted to this use are of two inch thickness; metal forms should give a flat surface on top of at least one and three-quarters inches. These can then serve as a guide for template, tamping machines, etc. The forms should be cleaned thoroughly and oiled with mineral oil before placing concrete against them. This will prevent the latter sticking to the wood or metal. The forms should be staked at least fifty feet in advance of placing the concrete.

Before depositing the concrete the subgrade should be moistened. As the concrete is discharged from the mixer it should be immediately distributed to the full depth of base required. Distribution should be such as to prevent separation of the ingredients. The concrete should then be consolidated to the specified depth, grade and cross-section by means of a template, using curbs, street railway track or side-forms as

guide rails. Where there are portions of the base not accessible to template finishing they can be hand-luted.

Where there are manholes, catch basins, monument boxes or similar structures, the concrete should not be desposited closely about them. The best practice is to leave a space of at least one inch around all such structures, this space being filled with expansion material.

At the end of each working period a bulkhead is placed at right angles to the centerline of the roadway and perpendicular to the pavement surface. The concrete is finished up to this bulkhead and when work is resumed the bulkhead is removed and the exposed face of the concrete base thoroughly wetted before fresh concrete is placed against it. At this point it might be well to state that partially hardened mortar or concrete should never be remixed with water and used, as a greatly inferior article always results.

Concrete should never be mixed in a temperature lower than 32 degrees Fahrenheit, unless the aggregate is heated in advance of mixing so that when the concrete is deposited on the subgrade it has a temperature of not less than sixty degrees. Even then it should be protected by covering to prevent its freezing. Concrete should never be deposited on a frozen subgrade.

Rolled Bases

Gravel, Stone or Slag

Where either gravel, crushed stone or crushed slag is used for the base it should be composed of durable particles together with sufficient fine material for binding purposes. In the case of gravel this fine material is generally sand, whereas in the case of crushed stone or slag it is often screenings. All gravel should pass through a three inch screen, not more than seventy-five per cent. should pass through a three-fourths inch screen, and not more than twenty per cent. should pass through a No. 10 screen. Gravel should contain not less than ten per cent. and not more than twenty per cent. by weight of clay or other binding material.

In the case of slag base the particles should all pass through three inch and be retained on a one-quarter inch circular openings in a revolving screen. Crushed stone for base courses should all pass through three inch circular openings in a revolving screen.

In using any one of these three materials they should be spread to a depth approximately thirty per cent. greater than the finished rolled depth. Where mechanical spreaders are used, care should be taken

THE GRAVEL BASE

Putting the finishing touches on a gravel base. It has just been thoroughly rolled and uniformly compacted previous to spreading the sand cushion. Old gravel roads make excellent bases for brick surfaces.

ROLLED STONE BASE

Approximately seventy-five miles of brick pavement on the National Road is laid on common crushed sandstone quarried along side of the road. Such bases are comparatively inexpensive where a supply is locally available. When thoroughly rolled and uniformly compacted crushed stone makes the best kind of a base.

not to disturb the subgrade. After the material has been spread to the prescribed thickness it should be harrowed sufficiently to loosen any cores formed by dumping. This harrowing should continue until the distribution is uniform.

. Then follows the rolling and this must be exceedingly thorough. A three wheel self-propelling roller weighing not more than ten

CRUSHED SLAG BASE

Blast furnace slag was used as the base course on this job. After thorough rolling and uniform compaction it often "sets up" under the brick surface in much the same manner as concrete. Where slag is available locally it makes a comparatively inexpensive base, and one that is entirely satisfactory.

tons or less than five tons has been found most practical for this work. Rolling begins at the edges and continues backward and forward until the center of the roadway is reached. The roller then proceeds to the opposite side of the road and again works toward the middle. Depressions which develop as a result of the rolling should be filled in with additional material and the rolling continued until the base is firmly compacted and shows no tendency to creep in front of the roller. Care should be taken during the rolling to see that the fine material enters the interstices of the base. Portions of the base inaccessible to the roller should be brought to surface and compacted by means of hand tamping

In the case of a gravel base, the clay or other binding material is usually already mixed with the gravel. Where slag or stone bases are used, screenings of the same material should be spread over the surface

after the base is rolled, and then swept into the interstices and further rolled. These screenings should all pass a one-quarter inch sieve. When necessary to obtain thorough consolidation, the base may be sprinkled with sufficient water to puddle the screenings into the voids.

Where edging and shoulders are desired, wooden forms of two by four inches should be set up on edge on the completed base and securely staked to act as guides for placing the brick wearing surface. After completion of the brick wearing surface a rolled shoulder of gravel, stone or slag at least twelve inches wide and as deep as the brick wearing surface and bedding course combined is built up upon the extended base. This shoulder should be thoroughly compacted as was the base. If practicable, the same roller may be used as is used to roll the brick surface. Thus the shoulder and surface may be rolled in the same operation, the wooden edging being allowed to remain in the pavement.

A bituminous bound shoulder sometimes is desired and often used where traffic is congested. In such cases the surface of the rolled shoulder should receive a bituminous penetration, not exceeding one and one-half gallons per square yard. Immediately after the bituminous material is applied the surface should be coated with a light application of screenings.

Recommended Specifications

Artificial Bases—Cement Concrete

MATERIALS: Concrete shall be composed of portland cement and of fine and coarse aggregate in the form of:

(a) Fine Aggregate: Sand, stone or slag screenings.

(b) Coarse Aggregate: Broken stone, gravel or crushed slag.

(c) Combined Aggregate: Bank-run gravel or crusher-run stone.

PORTLAND CEMENT: Portland cement shall conform to the definition and meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials, Serial Designation C 9-21.

FINE AGGREGATE: Fine aggregate shall consist of clean sand or screenings from hard, durable rock, gravel or slag, all of which shall be uniformly graded and which will pass through a one-quarter (¼″) inch sieve.

Fine aggregate shall be free from soft friable material, shale or slate, vegetable or other organic matter. It shall not contain clay or silt in excess of five (5) per cent. by weight.

COARSE AGGREGATE: Coarse aggregate shall consist of broken stone, gravel or crushed slag.

(a) *Broken Stone*—Broken stone used as the coarse aggregate shall be reasonably sound. It shall be uniformly graded in sizes between a maximum of what will pass a one and one-half (1½″) inch, and a minimum that will be retained on a one-quarter (¼″) inch circular opening in a revolving screen. It shall be reasonably clean and free from dust.

(b) *Gravel*—Gravel used as the coarse aggregate shall be composed of reasonably sound stone uniformly graded in sizes between a maximum of what will pass through

a one and one-half (1½″) inch, and a minimum that will be retained on a one-quarter (¼″) inch circular opening in a revolving screen. It shall be clean and free from soft, friable material, vegetable or other organic matter.

(c) *Crushed Slag*—Crushed slag used as the coarse aggregate shall be hard and sound. It shall weigh not less than eighteen hundred (1800) pounds per cubic yard. It shall meet the requirements of stone and gravel for sizes. Slag shall be reasonably clean and free from dust.

COMBINED AGGREGATE: Combined aggregate shall be of a character and quality that the separate ingredients shall meet the requirements for coarse and fine aggregate as above specified when separated, provided:

(a) That run-of-bank gravel may be used containing not more than seventy (70) nor less than fifty (50) per cent. by volume of fine aggregate.

(b) That run-of-crusher stone may be used containing not more than seventy (70) nor less than fifty (50) per cent. by volume of fine aggregate.

WATER: Water shall be clean, free from oils, acids, alkalies and vegetable matter.

MIXING: Ingredients for the concrete shall be separately measured and thoroughly mixed. Sufficient water shall be added to produce a concrete of the consistency designated by the engineer. The mixer shall be revolved not less than one minute after all ingredients are in the drum. Concrete shall be of uniform consistency with the stone thoroughly mixed with the fine aggregate, cement and water.

DEPTH: Upon the subgrade as prepared, concrete for the base shall be deposited, struck off and finished to the depth of ..... (..″) inches as provided in the plans.

PROPORTIONS: Cement, fine and coarse aggregate shall be mixed in the proportions of one (1) part cement, three (3) parts fine aggregate and six (6) parts coarse aggregate. If combined aggregate is used then the proportions shall be one (1) part cement to seven (7) parts combined aggregate.

FORMS: The forms used to retain the concrete shall be of wood or metal in case the curbing is not available for this purpose. They shall be straight and free from warp or bend. Forms shall be staked securely to line and grade and shall not deflect from position more than a one-quarter (¼″) inch. Ends of forms shall be joined tightly.

Wooden forms shall be of two (2) inch lumber; metal forms shall have a flat surface at the top of not less than one and three-quarters (1¾″) inches.

Forms shall be cleaned thoroughly and oiled with mineral oil immediately before placing concrete against them. They shall be staked not less than fifty (50) feet in advance of placing concrete.

DEPOSITING CONCRETE: Concrete for the base shall be deposited upon a moist subgrade. Concrete shall be discharged from the mixer uniform in consistency and without separation of the ingredients.

It shall be distributed immediately from side to side of the roadway to the full depth of base required. Concrete then shall be consolidated and surfaced to the required depth, grade and cross-section by means of a template, using curbs, street railway track or side-forms as guide rails.

No concrete shall be placed closer than one (1″) inch to all manholes, catch basins, monument boxes and similar structures projecting through the base course. This space shall be filled either prior or subsequent to the construction of the base as an expansion joint.

At the end of each working period a bulkhead shall be placed at right angles to the centerline of the roadway and perpendicular to the surface of the pavement, to which the concrete base shall be finished. When work is resumed the bulkhead shall be removed and the exposed face of the concrete wetted before fresh concrete is placed.

RETEMPERING: The use of partially hardened mortar or concrete, remixed with water, is prohibited.

FREEZING WEATHER: No concrete shall be mixed or deposited when the air temperature is less than 32°F., unless prior to mixing the aggregate shall have been heated so that, when placed, the temperature of the concrete shall be not less than 60°F. The pavement shall then be protected by sufficient covering to prevent it from freezing. In no event shall concrete be deposited on a frozen subgrade.

PROTECTION: After the concrete base has been laid it shall be protected from the traffic for at least ten (10) days, during which time it shall be frequently wetted.

At the end of this period no loaded or empty wagons, trucks or other vehicles that might injure the finished surface of the base, shall be permitted thereon without proper surface protection.

Recommended Specifications
Artificial Bases
Rolled Bases of Gravel, Stone or Slag
With or Without Shoulders and Bituminous Binding

MATERIAL AND SIZE: Broken stone or crushed slag as called for on the plans and in the bids for artificial base course, shall be run-of-crusher material of good grade and reasonably sound, that will all pass three (3″) inch circular openings in a revolving screen and be retained on one-quarter (¼″) inch openings. Gravel shall be composed of durable particles, together with clay or other suitable binding material. One hundred (100) per cent. shall pass through a three (3″) inch screen, not more than seventy-five (75) per cent. shall pass through a three-quarter (¾″) inch screen and not more than thirty (30) per cent. shall pass through a No. 10 revolving screen. The gravel shall contain not less than ten (10) nor more than twenty (20) per cent. by weight of clay or other suitable binding material.

DEPTH: The broken stone, crushed slag or gravel shall be uniformly distributed on the prepared subgrade to a depth approximately thirty (30) per cent. greater than the finished depth of ..... (..″) inches, called for on the plans, and thoroughly rolled in one course until the base is of uniform and thorough density throughout, conforming to the given grade and the cross section.

ROLLING: The roller used for this purpose shall be self-propelling tandem or three wheel type, weighing not more than ten (10) tons nor less than five (5) tons. The rolling shall commence at the edges of the pavement and work toward the center, and shall be continued until the base is thoroughly consolidated and shows no tendency to creep in front of the roller. During this operation the surface of the base shall be swept with stiff brooms so that all fine material shall enter the interstices of the base.

BINDER COURSE: With broken stone or crushed slag the base shall be bound with screenings of the same material that will all pass a one-quarter (¼″) inch sieve opening. The screenings shall be spread over the surface of the base and swept and rolled into the voids.

STONE SHOULDER: On pavements where the plans call for rolled shoulder and where curbs are not provided for on the plans for the project, the rolled base course of stone, slag or gravel shall extend at least twelve (12″) inches beyond the edges of the brick wearing surface as shown on the plans. On completion of the base course two by four (2″x4″) inch wooden forms shall be set on edge upon the prepared base and securely staked to act as guides for placing the brick wearing surface. The guide forms shall remain in place when the pavement is completed where shown in the plans.

After the completion of the brick wearing surface a shoulder of broken stone or crushed slag shall be placed. The width thereof shall be not less than twelve (12″) inches and the depth as built up upon the extended base shall equal the combined depth of the brick surface and the bedding course as shown on the plans. The shoulder shall be thoroughly compacted by rolling, using the same roller, if practicable, as specified for the brick surface.

BITUMINOUS BINDING: Where a bituminous bound base or shoulder is indicated on the plans, the surface of the rolled base or shoulder shall receive a bituminous penetration not exceeding one and one-half (1½) gallons per square yard.

Immediately after bituminous material is applied, the surface shall be covered with a light application of screenings.

CHAPTER VII

Worn Concrete, Macadam or Gravel Pavements For Bases

The vitrified paving brick is a contribution to public economy by reason of its availability and utility in affording renewed life to worn concrete, macadam or gravel pavements. Quantity production in the highway field in the last few years leaves us today with many miles of such pavements, which, without early attention, will become total losses early in life. Proper repairing of the concrete surface, the application of a bedding course and a brick surface, provide practically a new pavement at a comparatively small cost.

WORN CONCRETE PAVEMENTS AS BASES FOR BRICK SURFACES

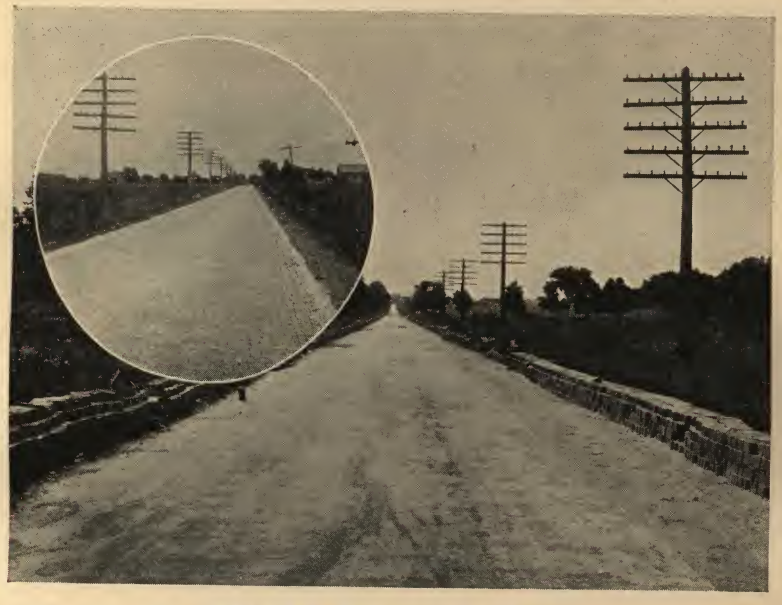
This illustrates the condition of a worn concrete pavement before cracks and depressions have been cleaned and filled prior to laying the sand cushion and brick surface. If such treatment is undertaken in time it is possible to obtain a brick pavement at a comparatively low cost because of the salvage value in the old pavement.

In reconstructing the concrete surface to make it satisfactory for base purposes, badly damaged portions should be removed and replaced with new concrete to the required depth. This treatment should be applied to all portions that have been damaged to the extent that they will not provide a uniform support for the wearing surface.

Cracks and other minor imperfections which impair its value for foundation purposes and make impossible an even bedding course, must be cleaned out and filled with bituminous material or cement mortar.

New concrete to replace damaged portions should be mixed according to the specifications for mixing concrete bases, except that where the quantity to be replaced does not make machine mixing economical, it may be mixed and placed by hand. When such treatment is completed the reconstructed base should be reasonably smooth and even.

In preparing worn macadam or worn gravel pavements for bases, they should be reconstructed by shaping, adding new material where



READY FOR THE BRICK SURFACE

A worn concrete pavement after the cracks and depressions have been cleaned and filled with new material. The inset in the circle shows the brick surface before asphalt filler has been applied.

necessary, and by rolling to form a uniformly dense and thoroughly compacted base. The broken stone, crushed slag or gravel used in the reshaping should conform to the requirements as outlined previously for such base course materials.

All dirt, dust or refuse should be removed from the existing surface. Where this surface is broken stone, crushed slag or gravel, it should be scarified only in case scarifying is necessary to obtain the required grade alignment and to obtain a uniformly dense surface. All depressions and irregularities should be corrected, and the whole reshaped and brought to the specified line, grade and cross section.

Rolling follows to thoroughly and uniformly compact the base. It will be helpful to thoroughly wet the road during this operation to

assist in compaction. Where depressions occur as a result of the rolling, they should be filled with additional materials and re-rolled with a self-propelling roller, weighing not to exceed ten tons. The rolling should continue until the material shows no tendency to creep in front of the roller. Screenings or sand, not exceeding one-quarter inch in maximum

WORN MACADAM PAVEMENT BEING PREPARED FOR BRICK SURFACE
Scarifying is undertaken only when necessary to attain the proper grade. The less the old pavement is disturbed the better base it makes. The aim always is to preserve the compaction produced by years of traffic.

size, are used as a binder to fill the interstices. This is done by the use of stiff brooms of ratan or wire.

Where the existing surface overlies a telford or other large stone base, any projecting stone should be napped off in the re-shaping.

The old macadam or gravel should not be disturbed or scarified below the newly established grade line.

Recommended Specifications
Reconstructed Base Course—Worn Concrete Pavements
or
Old Concrete Bases

DESCRIPTION: Worn concrete pavements or old concrete base courses used as the base for brick wearing surfaces shall be reconstructed, if required, under the following conditions:

(a) Where existing concrete remaining is inadequate to meet the requirements of

depth as shown on the plans, such portions shall be removed and replaced with new concrete to the depth required.

(b) Such portions of existing pavement as have been destroyed or damaged so as to prevent uniform support for the wearing surface shall be replaced with new concrete.

(c) Cracks, or other minor imperfections of the surface which might impair its value for foundation purposes and make impossible an even bedding course, shall be cleaned and filled with bituminous material, cement mortar, or finely crushed slag or stone thoroughly wetted and compacted.

MATERIALS AND MIXING: Materials and mixing for concrete required for replacements shall conform to the specifications for Concrete Base, except that, where the quantity of concrete to be replaced does not make machine mixing economical, concrete may be mixed and placed by hand.

The surface of the reconstructed pavement as prepared for laying the brick thereon shall be reasonably smooth and even.

Recommended Specifications
Reconstructed Base Course—Worn Macadam or Gravel Roads

DESCRIPTION: Worn macadam or gravel wearing surface used as the base for brick pavements shall be reconstructed by shaping, adding new material, where required, and by rolling to form a uniformly dense and thoroughly compacted base.

MATERIALS: Broken stone, crushed slag or gravel used in reshaping the base shall conform to the specifications under Rolled Bases.

The existing road surface shall be thoroughly cleaned of all dust, earth or refuse. It shall be brought to required grade, cross section and condition for laying the brick thereon as follows:

Where existing surface is broken stone, crushed slag or gravel, it shall be scarified, if needed, to obtain a uniformly dense surface for the entire width of the pavement and to a depth sufficient to remove all depressions and irregularities and to permit of uniform reshaping. The existing road must not be disturbed or scarified below the newly established grade line.

After loosening, the material shall be shaped to conform to grade and cross section as shown in the plans by the addition of new material if required.

ROLLING: The reconstructed base shall then be compacted by rolling to uniform and thorough density and the addition of screenings or sand not exceeding a one-quarter (¼") inch in maximum size as a binder. During this operation the road shall be thoroughly wetted to assist in the compaction of the material.

The base shall be brought to the required uniformity and density by a self-propelling roller weighing not to exceed ten (10) tons. Rolling shall begin at the shoulders and continue backward and forward until the center of the roadway is reached. Depressions developing during rolling shall be brought to the required surface by the addition of material and rerolling. Rolling shall continue until the base is firmly consolidated and shows no tendency to creep in front of the roller During the rolling the surface of the base shall be swept with stiff wire or rattan brooms so that all fine material shall enter the interstices of the base.

TESTING: Where the existing surface overlies a telford or other large stone base, projecting stones, if any, shall be napped off to a uniform elevation. All depressions or irregularities shall be brought to the required grade and cross section by the addition of new material, if required, and by rolling.

CHAPTER VIII

Bedding Course
Sand, Granulated Slag, Slag Screenings or Limestone Screenings

The major purpose of a bedding course is to permit the finishing of the brick surface to a perfect level. This bedding course is also occasionally referred to as a cushion, but its action as such is very doubtful. The bedding course is usually sand although granulated slag, slag screenings or limestone screenings are equally serviceable and frequently preferred because of the lime content in these materials, causing them to "set up" in time, thus preventing any shifting of the bedding course. The bedding course material is evenly and uniformly

THE SAND BED

Illustrating the rolling of the sand bed to insure its uniformity. Absolute uniformity of the sand bed means continued perfect alignment of the brick surface. Any depressions developed by rolling are filled in, the surface again struck off with the template and then re-rolled.

spread upon the base to a finished depth of not more than one inch and not less than one-half inch. None of these materials should exceed one-quarter of an inch in grain size. They may contain fine

material up to fifteen per cent. by weight. In the case of sand this fine material may be loam or clay.

A template and often a small hand roller are best used to shape the bedding course. Curbs, guide forms, or railway tracks are used as guides. In cases where the roadway is too wide to permit a template to span the entire distance, the bedding course has to be finished in sections. Scantling laid on the base may be used as guide rails in such instances.

Care should be taken to see that the bedding material is evenly distributed. It should be thoroughly raked where compacted by dumping. Upon the uniformity of this bedding course depends to a great extent the continued perfect alignment of the brick surface. A small hand roller can often be used to good advantage to compact the bedding course, and there are occasions when its use should be

SPREADING SAND BED

Illustrating how the template, riding on the curbs, is pulled forward to spread the sand bed to the proper grade. Any depressions are filled in and the template used again until the surface is perfect.

insisted upon by the engineer, particularly when the depth of the bedding course is variable due to an uneven surface of the base course or when the average depth of the bedding over a given area exceeds one inch. The roller used for this work should be not less than thirty-six inches in diameter, twenty-four inches in width and weigh not less than ten pounds per inch of width.

The bedding course should be struck off at least twice with a

template and then rolled if necessary. Any depressions developing should be filled in, and the bed again struck off with the template. This operation is continued until a perfect alignment is presented.

After once thoroughly spread and shaped, the bed should never be disturbed before laying the brick.

Recommended Specifications
Bedding Course
Sand, Granulated Slag, Slag Screenings or Limestone Screenings

DESCRIPTION: Upon the prepared base after it has been thoroughly cleaned of all dirt and debris, shall be spread a bedding of sand, granulated slag, slag screenings or limestone screenings, as called for in the plans, not more than one (1″) nor less than one-half (½″) inch in finished depth.

SIZES: Bedding material shall not exceed one-quarter (¼″) inch in maximum grain size. It may contain fine material passing a No. 20 standard mesh sieve, not exceeding fifteen (15) per cent. by weight. In the case of sand, this fine material may be loam or clay.

SHAPING: Bedding shall be shaped to a true surface parallel with the surface of the finished roadway by means of a template extending the entire width of the roadway, drawn forward upon the curbs or other guide rails as provided. When the width of the roadway precludes the use of a template spanning the entire distance, the bedding shall be shaped in sections, using scantling laid upon the base as guide-rails. The bedding course shall be struck off at least twice with the template. Any depressions developing shall be filled in and the bed again struck off with the template. This operation shall be continued until perfect alignment is presented.

ROLLING: If directed by the engineer, in addition to shaping with a template, the bedding course shall also be compacted with a hand roller. The roller shall be not less than thirty-six (36″) inches in diameter, twenty-four (24″) inches in width and weigh not less than ten (10) pounds per inch of width.

The bedding course shall be struck off with the template and then rolled. Any depression existing shall be filled in, struck off with the template and again rolled. This operation shall be repeated until perfect alignment is presented.

HAND FINISHING: When the use of the template and guide rails is impracticable in finishing the bedding surface, it shall be shaped to the surface required by hand lutes.

NO DISTURBANCE: The bedding shall not be disturbed after final shaping prior to laying the brick.

CHAPTER IX

Vitrified Paving Brick and Wearing Surface

It is obvious that the ideal pavement wearing surface should possess the following characteristics and attributes:

It should be *hard* to withstand abrasive wear. It should be *tough* to withstand impact. It should be *dense* so as not to absorb moisture. It should be *smooth* to provide comfort and the passage over it of vehicles at an expenditure of the least possible motive power and with the least possible wear and tear on the vehicle or any of its parts. It should not be "slick," and in the interest of safety alone, should offer good tractive resistance. It should be sufficiently flexible to permit of expansion and contraction, due to temperature and moisture influences, without damage to the pavement.

The vitrified paving brick, as a unit, is hard, tough, dense and smooth. It offers good tractive resistance, and is never slick, whether wet or dry. When laid in a pavement with asphalt filler, the resultant surface meets the necessary requirements for flexibility without losing any of the attributes of hardness, toughness, density and smoothness. Furthermore, such a surface is quiet, waterproof, produces no dust, absorbs no filth and is sanitary.

As to quality, vitrified paving brick should be evenly burned and thoroughly annealed. In addition to being hard and tough, they should possess a texture and structure uniform in appearance and free from open or marked lamination.

The transverse dimensions of vitrified paving brick should be three inches by four inches or three and one-half inches by four inches, and variation from these dimensions should not exceed one-eighth of an inch. The length should be eight and one-half inches and variation from this dimension should not be more than one-half inch.

Wire-cut brick are used for wearing surfaces three inches, three and one-half inches or four inches in depth; repressed brick for wearing surfaces four inches in depth.

As to shape, the ends of the brick may be double beveled not to exceed one-eighth of an inch. Where lugs are specified, they should be not less than two or more than four in number and should extend from the body of the brick not to exceed one-quarter of an inch. In

the case of hillside brick, designated as a special for paving grades in excess of five to eight per cent., depending on their location, one or more longitudinal edges or faces of the brick should be chamferred or grooved not more than three-quarters of an inch.

Vitrified paving brick are made from shales or from fire clays, but not all shale or fire clay is suitable.

The raw materials for vitrified paving brick must have chemical and physical characteristics that permit of incipient fusion at a higher temperature than is required in making common building brick. This is known as vitrification. It is the process in which the

A TYPICAL PAVING BRICK PLANT

The shale pit is in the background. The big building houses the dry-pan, pug-mill, die, cutting machine and the like. The drying tunnels are in the low, flat roofed building. The kilns are reached by tracks leading from the dryer. Stock piles can be seen this side of the kilns.

myriads of small particles of finely ground material become fused in another state without melting to a degree that would permit the brick to lose their shape. The result is a new material that is dense, tough, hard and durable. Briefly the principal steps in manufacture are as follows:

The shale or fire clay is dug from open pits (Fig. 1) or is mined. In either case the material is crushed and ground into fine particles in what is known as the dry pan (Fig. 2) where wheels, weighing several tons and known as mullers, transform the material into a fine powder.

The fine, dry clay or shale is mixed with water in a pug mill (Fig. 3) until it attains the consistency of stiff mud. This plastic mixture is

Fig. 1.—*The Pit.*

Fig. 2.—*Dry Pan and Mullers*

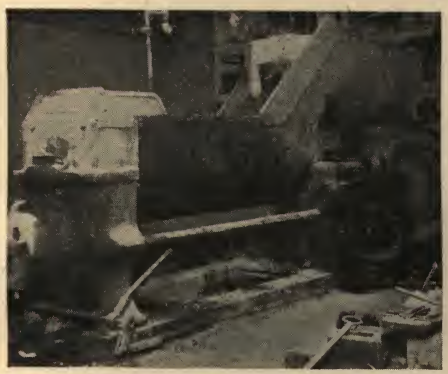


Fig. 3.—*Pug-Mill.*

Fig. 4.—*The Die.*

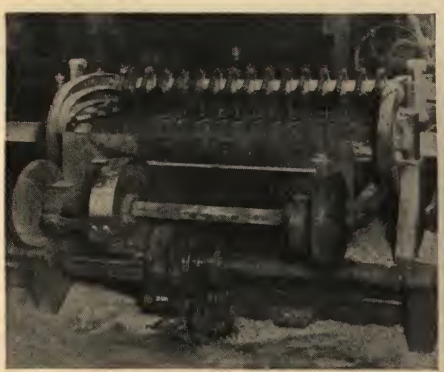


Fig. 5.—*The Cutting Machine.*

Fig. 6.—*Bee-hive Kiln.*

then forced through a rectangular orifice named the "die" (Fig. 4) by a powerful augur. It emerges from the die onto a moving belt in a continuous stream much as tooth paste emerges from its container.

As the bar of clay progresses from the die it passes through the cutting machine (Fig. 5) where, by means of tightly strung piano wires, automatically swinging backward and forward, the bar is cut up into bricks. These are immediately stacked on cars and conveyed into the dryers where waste heat from cooling kilns evaporates a large part of the moisture introduced in mixing.

After drying for from 36 to 48 hours in temperature ranging from 125 to 250 degrees Fahrenheit, the brick are taken from the drier and stacked in the kilns (Fig. 6) for burning. The burning and vitrifying process is the climax of the manufacturing process as well as the most important stage. All previous steps are preparatory for this one.

The process of vitrifying — requiring a maximum temperature ranging from 1,800 to 2,200 degrees Fahrenheit, depending upon the characteristics of the particular material—and the subsequent cooling requires from two to three weeks.

Rigid inspection is practiced in the manufacture of paving brick. At least four times during manufacture each brick is individually handled and visually inspected. After manufacture there is provided the tests of the Standard Specifications for Paving Brick of the American Society for Testing Materials. When brick are submitted to the rattler test of these specifications, they shall not lose more than the per cent. of weight agreed upon by the purchaser and the manufacturer. This allowed loss is determined by the use to which the brick are to be put. It is always desirable that the brick be officially inspected and tested at the place of manufacture before shipment, and it is hardly necessary to say that the rattler used for conducting such tests be maintained and operated and the test conducted strictly in accordance with the Standard Specifications of the Society. Tests for cross breaking and absorption are no longer necessary and are not made, as any brick passing the rattler test of the American Society for Testing Materials will also pass the former tests for cross breaking and absorption.

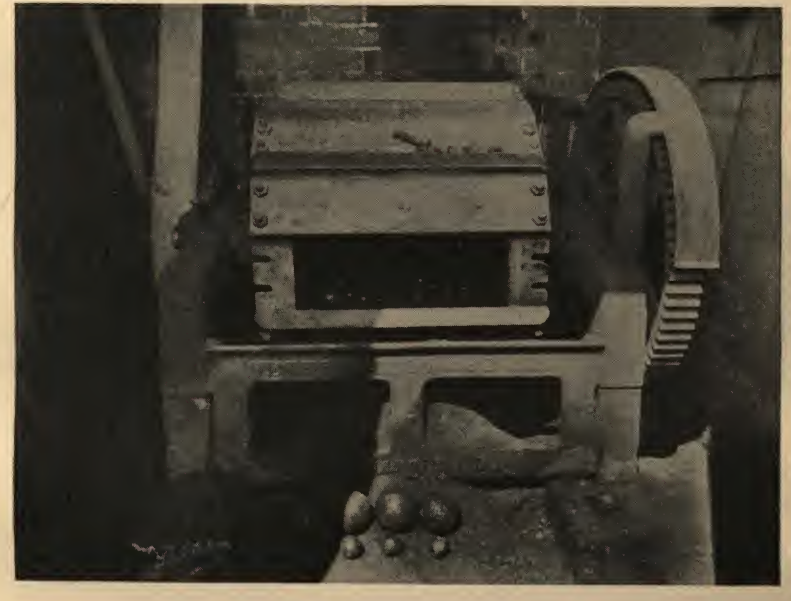
The following pertinent paragraphs taken from the Standard Specifications for Paving Brick of the American Society for Testing Materials, Serial Designation C 7-15, are quoted:

I. THE RATTLER TEST

"1. *Place of Sampling*—In general, where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination or on the street, when delivered ready for

use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of test prior to shipment, shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Part II, Visual Inspection.

"2. *Method of Selecting Samples*—In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection as provided in Part II, except, that where controversy arises, whole tests may be selected to determine the admissibility of certain types of portions of the lot having a characteristic appearance in common. In cases



THE STANDARD RATTLER

The standard rattler of the American Society for Testing Materials is designed to provide an abrasion test for vitrified paving brick. Large shot, small shot and paving brick constitute the charge. The brick are weighed before they are put in the rattler and again weighed when they come out, thus establishing the average loss.

where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

"3. *Number of Samples per Lot*—In general, one sample of ten bricks shall be tested for every 10,000 bricks contained in the lot under

consideration; but where the total quantity exceeds 100,000 the number of samples tested may be fewer than one per 10,000 provided that they shall be distributed as uniformly as practicable over the entire lot.

"5. *Storage and Care of Samples*—Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100°F. before testing.

"10. *The Brick Charge*—The number of bricks per test shall be ten for all bricks of so-called 'block size,' whose dimensions fall between 8 and 9 inches in length, 3 and 3¾ inches in breadth and 3¾ and 4¼ inches in thickness. (Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.) No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

"15. *Basis of Acceptance or Rejection*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regarded and a portion selected for further tests as provided in Section 16.

"16. *Range of Fluctuation*—Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made, wherever the standard may be fixed.

"In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than two per cent., then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than two per cent. the required standard, then that portion of the lot shall be rejected.

"If in any lot of brick, two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

"17. *Fixing of Standards*—The percentage of loss which may be taken as the standard, will not be fixed in these specifications, and shall remain within the province of the contracting parties. For the

information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General Average Loss percent	Max. permissible Loss percent
For bricks suitable for heavy traffic . .	22	24
For bricks suitable for medium traffic .	24	26
For bricks suitable for light traffic . .	26	28

"Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind and amount of traffic to be carried, and the quality of paving bricks available.

"(Where brick of larger or smaller sizes than the dimensions given for the so-called 'block size' whose dimensions fall between 8 and 9 inches in length, 3 and 3¾ inches in breadth and 3¾ and 4¼ inches in thickness, are to be tested the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.)

"18. *Culling and. Retesting*—Where, under Sections 15 and 16 a lot or portion of a lot of bricks is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall then be resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

"19. *Payment of Cost of Testing*—Unless otherwise specified the cost of testing the material as delivered or prepared for delivery up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also Section 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller whether the material is finally accepted or rejected."

II. Visual Inspection

"It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use, and prior to or during the laying, to cull out and reject upon the following grounds:

"20. All bricks which are broken in two or shipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the

purchaser to use them so far as practicable in obtaining the necessary half bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

"21. All bricks which are cracked in such a degree as to produce defects such as are defined in Section 20, either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, burning or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

"22. All bricks which are so off-size, or so misshapen, bent, twisted, or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other paving specifications.

"23. All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude as provided in Section 2, and if in either or both tests, the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller shall pay for the cost of the test. But if under such procedure, the bricks which have been tested as objectionable, shall pass the rattler test, both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay for the cost of the test.

"24. All bricks which differ so markedly in color from the type of average of the shipment, as to make the resultant pavement checkered or disagreeably mottled in appearance. This Section shall not be held to apply to the normal variations in color which may occur in theproduct of one plant among bricks which will meet the rattler test as referred to in Section 15, 16 and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture."

* * * * *

When brick are delivered to the job they should be carefully handled to avoid chipping, and should be piled neatly outside of the roadway before the grading is completed. The piling should be in sufficient quantity to complete the brick surface required. They should be kept clean, free from soil, and must be clean when laid in the pavement.

The Brick Surface

The brick can be conveyed to the droppers by hand from the side of the roadway, using either palletts or brick clamps. They also can be moved by mechanical conveyors. In any event they should be

THE VITRIFIED BRICK SURFACE

This photograph shows the brick surface before the asphalt filler has been applied. It also illustrates one method of conveying the brick to the droppers. A stone screenings cushion can be seen in the foreground.

LAYING THE BRICK

The brick are mechanically conveyed from the side of the road, arranged in piles and dropped into the pavement by the "dropper." The latter lays four courses across the pavement at a time.

arranged for the droppers in such manner that in the regular operation of laying them upon the bedding, the better face or side will be upward.

Brick are laid on the bedding course in successive courses, usually four courses at a time. Where lug brick are used, the lugs are turned in one direction. Alternate courses of brick begin with one-half brick so that the end joints are staggered, the broken end of the half-brick is turned in toward the center of the pavement. Each course of brick must be laid true and even, and perpendicular to the edge of the pavement. Deviation from a straight line ought never to exceed two inches in thirty feet. The dropper, and any men carrying brick to him, should stand on the brick surface already laid, and not on the bedding course. This is necessary to prevent even the slightest disturbance of the bedding course after it is completed.

Laying brick around curves as they exist in the street or highway is an important item as few paving projects are straight throughout their entire length. Various plans are followed by different engineers and contractors. The two in most common use and giving the best service are simple and easy to follow. The first method used on curves of long radius, is to lay the brick in radial courses allowing the joints between courses to widen to a maximum of one-half inch on the outer edge of the curve and pavement. The second method used on curves of short radius, consists in laying the brick in radial courses and filling in the space between courses with full brick or portions thereof, not less than three inches in length laid longitudinally and at right angles to one of the transverse joints. By building transverse courses of varying length it is possible to lay brick around the curve without having to use any piece smaller than three inches or more than one full brick in length.

After the brick are in their position in the pavement, they should be swept and finally inspected. Those not laid with the better face or side upward are turned over and all brick not meeting requirements as to quality must be removed. Slightly chipped brick, otherwise acceptable, are usually kept in the pavement since experience has taught that slight chipping does not affect the utility or durability of the material.

Any surplus brick of good quality are moved forward and used in the pavement as occasion permits. Rejected brick usually are suitable for batting and are used for that purpose.

A self-propelled tandem roller weighing approximately three tons is used to roll the brick surface. As previously described, the rolling should begin at the edge of the pavement and continue backward and forward, until the center of the pavement is reached. The roller then passes to the other edge of the pavement and repeats the operation on the opposite side of the road. This may be followed by rolling at an

angle with the edge of the pavement, entirely across from side to side. This operation should then be repeated in the opposite direction. Any brick broken or otherwise damaged in the rolling should be removed, and perfect brick substituted. Final rolling should always be parallel with the center line of the roadway. Where mechanical rolling is impossible, hand tamping may be resorted to.

To finally test the surface, after seeing that it conforms to grade and cross-section, a six-foot straight edge should be used. It is laid

ROLLING THE BRICK

A 3-ton roller is used to bring the brick to a smooth surface and finally perfect the alignment of the pavement. A straight-edge reveals any depressions or high spots. In such cases the brick should be liftedout,the sand cushion adjusted, the brick replaced and re-rolled. Proper construction and careful inspection more than pays for itself in the building of any type of pavement.

parallel to the center line of the roadway and any depression of more than one-quarter of an inch must be corrected.

Recommended Specifications
Vitrified Paving Brick and Surface

QUALITY: Vitrified paving brick shall be evenly burned and thoroughly annealed. They shall be hard and tough. The texture and structure of the brick shall appear uniform and shall disclose freedom from open or marked lamination.

SIZES: The transverse dimensions of vitrified paving brick, as shown in the plans and designated in the bids, shall be three (3″) inches by four (4″) inches or three and one-half (3½″) inches by four (4″) inches and variation from these dimensions shall not exceed one-eighth (⅛) of an inch. The length of the brick shall be eight and one-half (8½″) inches and variation from this dimension shall not exceed one-half (½) of an inch.

STYLE OF BRICK AND DEPTH OF WEARING SURFACE: Wire-cut brick shall be used for wearing surface as indicated on the plans for the project,

three (3″), three and one-half (3½″) or four (4″) inches in depth; repressed brick for wearing surface four (4″) inches in depth.

SHAPE: Ends of the brick may be double-beveled not more than one-eighth (⅛″) of an inch. Lugs, if any, shall be not less than two nor more than four in number, extending from the body of the brick no more than one-quarter (¼″) of an inch. Special brick for hillside grades, exceeding from five to eight per cent., shall have one or more longitudinal edges or faces chamferred or grooved not more than three-quarters (¾) of an inch.

INSPECTION AND TESTS: Shipments in excess of 100,000 brick to one or more projects under the jurisdiction of the engineer, shall be inspected and tested at the place of manufacture. Shipments of less than 100,000 brick may at the option of the engineer be tested at the plant or on the cars or street after delivery. Brick shall not lose of their weight more than..... (..) per cent. when tested in the standard rattler of, and in accordance with, the Standard Specifications for Paving Brick of the American Society for Testing Materials, Serial Designation C 7-15. The forementioned standard specifications shall likewise govern visual inspection and are hereby made a part of these specifications.

DELIVERY AND PROTECTION OF BRICK: Brick shall be handled carefully and piled neatly outside the roadway, before grading is completed, in sufficient quantity to complete the brick surface; provided: that they may be brought upon the work immediately prior to laying if delivery can be accomplished with no injury or delay to work in progress. Brick shall be so piled and protected that they will be kept clean. They shall be clean when they are laid in the pavement.

LAYING THE BRICK:

CONVEYING THE BRICK TO DROPPERS: Brick shall be carried from the side of the roadway to the droppers by hand, on pallets, or in brick clamps, or mechanically on conveyors. They shall be arranged for the droppers so that, in the regular operation of laying them upon the bedding, the better face or side will be upward.

LAYING THE BRICK: Upon the bedding as prepared, the brick shall be laid in successive courses with the better face or wire-cut side upward. Lugs, if any, shall be turned in one direction. Alternate courses of brick shall begin with one-half a brick. Each course shall be completed by batting in at the end, if necessary, with fragments of brick at least three (3″) inches long, a portion of the next adjoining brick being broken off if necessary to give the minimum three (3″) inch bat at the end of the course. The fractured end of cut or trimmed brick shall be turned toward the center of the roadway. Every course of brick shall be laid true and even, perpendicular to the edge of the pavement; no course shall deviate from a straight line more than two (2″) inches in thirty (30) feet. All brick laying shall take place over brick already laid, and shall follow the completion of the bedding within fifty (50) feet.

LAYING THE BRICK AROUND CURVES: Where the curvature of the street or highway permits, the brick shall be laid in radial courses, allowing at the outside of the curve a space between the courses, not exceeding one-half (½) of an inch. Where the curvature of the street exceeds the above, the brick shall be laid in radial courses transversely across the roadway and in the intervening space between courses the brick shall be laid longitudinally at right angles to one of the transverse courses at each successive closure.

No portion of a brick less than three (3″) inches in length shall be used for batting such closures and the amount of space to be batted in shall, by varying the length of the successive transverse courses, not exceed a whole brick.

In no case shall brick be broken longitudinally to make a closure on a curve.

INSPECTION: Immediately after laying the brick, the surface of the roadway shall be swept and inspected. Brick not laid with the better face or side upward shall be turned over and those not meeting the requirements for quality shall be removed by the contractor and replaced by acceptable brick. Those slightly chipped but otherwise acceptable shall be used.

SURPLUS BRICK: Surplus brick shall be moved forward and used in the roadway. Rejected brick suitable for batting shall be used for that purpose. All remaining brick shall be neatly piled at the side of the roadway.

ROLLING: The surface of the roadway shall then be rolled by a self-propelling tandem roller weighing approximately three (3) tons.

Rolling shall begin at the edge of the pavement and continue backward and forward until the center of the pavement is reached. The roller shall then pass to the

other edge and repeat the operation to the center. The rolling may then be at an angle obliquely with and entirely across the pavement. This operation shall then be repeated in the opposite direction. Broken or otherwise injured brick shall be removed and replaced before final rolling takes place. Final rolling shall be parallel with the center line of the roadway. Portions of the surface not accessible to mechanical rolling shall be hand tamped.

TESTING THE SURFACE: The completed surface of the roadway shall conform to grade and cross section as provided in the plans. Depressions exceeding a one-quarter (¼") inch as tested with a six (6) foot straight edge laid parallel to the center line of the roadway, shall be corrected.

CHAPTER X

Asphalt Filler

In December, 1921, the National Paving Brick Manufacturers Association declared its preference for the asphalt filled types of vitrified brick pavements for general use, such preferment, however, being without prejudice to any type which may possess peculiar adaptation to special local conditions.

Many years of experience with, and observation of all types of vitrified brick pavements, lie back of the definite commitment of the Association to the asphalt filler and the flexibility it provides in the

ASPHALT FILLER

Common coal buckets are being used on this job to carry the heated asphalt from the kettle to where it is being applied. It is carefully squeegeed into the joints as it is poured from the bucket.

vitrified brick surface. In its use and application there are only a few principles to be observed. Either oil asphalt or natural asphalt may be used for this filler, care being taken that it conform in all respects with the specifications and tests provided for it by the National Paving Brick Manufacturers Association. It should be heated to a

temperature not exceeding 200°Centigrade or 390°Fahrenheit and it must be applied at a temperature of not less than 350° Fahrenheit. This high temperature is necessary to insure the asphalt filling the

DIRECT FROM KETTLE

Here the asphalt flows direct from the kettle to the pavement through a hose or pipe. This is perhaps a quicker and more efficient method of application than pouring from buckets.

THE SAND DRESSING

Illustrating the application of sand dressing immediately after the filler has been put on. This dressing, sometimes fine screenings instead of sand, is immediately rolled to bed it in the thin asphalt coating which remains on the surface of the brick.

joints between the brick sufficiently to seal the surface and adequately bond the brick.

Before the application of filler it should be certain that the brick are clean and dry. They should be swept thoroughly. If the brick are either wet or dirty, the filler cannot be expected to penetrate the joints as perfectly as is necessary to insure proper construction.

The filler should flow freely into the joints. It, therefore, must be in a very liquid state and should never be applied in a temperature so cold as to prevent free flowing.

The favored method of getting the filler well into the joints is by the use of squeegees, operated slowly backward and forward at an angle with the joints. Squeegeeing should continue and filler should be applied until the joints appear full and only a thin coating of asphalt remains on the surface of the brick. A settlement of the filler in the joints of not more than one-eighth of an inch, is not harmful. The filled

A FINISHED PAVEMENT

A crushed stone base, sand cushion, plain wire-cut vertical fibre brick and asphalt filler.

surface should at once be sprinkled with a thin coating of dry stone screenings, sand or granulated slag of such size that all will pass a one-quarter inch sieve. Rolling follows to thoroughly bed the dressing into the asphalt coating, and the pavement may then be opened to traffic without further delay.

Recommended Specifications
Oil Asphalt Filler—Squeegee Method

DESCRIPTION: Asphalt filler shall be homogeneous, free from water, and shall not foam when heated to 200°C. (392°F.). It shall meet the following requirements:

(a) Flash Point: Not less than 200°C. (392°F.).
(b) Melting Point: Ring and Ball. 65°C. (149°F.) to 110°C. (230°F.).
(c) Penetration: At 0°C. (32°F.) 200 gms., 1 min., not less than 10.
At 25°C. (77°F.) 100 gms., 5 sec., 30 to 50.
At 46°C. (115°F.) 50 gms., 5 sec., not more than 110.
(d) Loss on Evaporation: 163°C. (325°F.), 5 hrs., less than 1.0 per cent.
(e) Ductility: Not less than 3.
(f) Total Bitumen: (Soluble in carbon disulphide) not less than 99 per cent.
(g) Per Cent of Total Bitumen: (Soluble in Carbon Tetrachloride) not less than 99 per cent.
(h) Reduction in Penetration: At 25°C. (77°F.), due to heating specified under Loss on Evaporation, not more than 50 per cent.

TESTS: Tests for the above requirements shall be made according to the following methods:

(a) Flash Point: (Open Cup) U. S. Department of Agriculture Bulletin 314, Page 17.
(b) Melting Point: American Society for Testing Materials, Standard Method. Serial Designation D-36-19.
(c) Penetration: American Society for Testing Materials, Standard Method. Serial Designation D-36-19.
(d) Loss on Evaporation: (Volitalization): U. S. Department of Agriculture Bulletin 314, Page 19; 50 gram sample.
(e) Ductility: American Society of Civil Engineers, Transactions, Vol. LXXXII, 18, Page 1460.
(f) Total Bitumen: U. S. Department of Agriculture Bulletin 314, Page 25.
(g) Per Cent of Total Bitumen: (Carbon Tetrachlorid) U. S. Department of Agriculture Bulletin 314, Page 29.
(h) Reduction in Penetration: See Test for Penetration.

HEATING: Filler shall be heated to a temperature not exceeding 200°C. (392°F.). It shall be applied at a temperature of not less than 177°C. (350°F.). The heater shall be equipped with a thermometer capable of registering at all times the temperature of the filler.

CLEANING THE SURFACE: Brick shall be clean and dry when the filler is applied. Immediately before filling the joints the surface of the brick shall be swept clean. All brick shall be filled and a surface dressing applied on the day of laying. Filler shall not be applied if the brick are wet nor if air temperatures are such that the filler will not flow freely into the joints.

FILLING AND SQUEEGEEING: Filler shall be removed from the heater and applied promptly to the pavement before cooling. Filler shall be worked into the joints by means of squeegees operated slowly backward and forward at an angle with the joints. Squeegeeing shall continue until the joints appear full and a thin coating of asphalt remains upon the surface of the brick.

SURFACE DRESSING: Immediately after the joints are filled, a thin coating of dry stone screenings, slag screenings, sand or granulated slag shall be spread upon the surface of the pavement. Top-dressing shall be of such sizes that all will pass a one-quarter (¼") inch sieve. As soon as the dressing is spread the surface of the pavement shall be rolled thoroughly to bed the dressing into the asphalt coating.

OPENING TO TRAFFIC: The brick roadway may be opened to traffic immediately upon completion of the surface dressing.

CHAPTER XI

Sand Filler

Sand filler for brick pavements has been and still is used with the utmost success in numerous and widely scattered sections of the country, particularly where there is an abundance of sand available locally at low cost. Like asphalt filler, it permits a flexible surface, which is a most important consideration.

It has been perhaps most frequently used with the repressed type of brick of which the edges are slightly rounded, but is being successfully used with the plain wire cut brick. Where cost or other considerations prohibit the use of asphalt for filler, sand provides an acceptable substitute.

SAND FILLER

Sand filler can be applied easily with the crude brush drag. Stiff brooms are used in many instances.

Clean, dry sand of such grain size that all will pass a No. 12 sieve should be used for filler purposes. It is spread upon the brick surface to a depth of not less than one-half inch and is then swept into the

joints until they are completely filled. Stiff brooms or brush drags are customarily used, and an excess of sand is permitted to remain on the surface. The street may be opened to traffic immediately after the joints are filled.

Recommended Specifications
Sand Filler

DESCRIPTION: Joints between the brick shall be filled with clean, dry sand of such sizes that all will pass a Number 12 sieve.

FILLING: Sand shall be spread upon the surface of the roadway to a depth of not less than a one-half (½") inch. It shall then be swept into the joints completely filling them.

SWEEPING: Sand shall be swept into the joints by stiff brushes or by weighted brush drags drawn over the surface of the pavement. An excess of sand shall remain upon the surface.

OPENING TO TRAFFIC: Immediately after the joints are filled, the roadway may be opened to traffic.

CHAPTER XII

Vitrified Brick Pavements with Street Railway Tracks

In cities the proper construction of the brick pavement wearing surface in the street railway track area, between and adjacent to the rails, deserves special consideration.

The pounding, swaying and vibration of heavy street cars, puts a heavy burden on the substructure of a street railway track, and likewise on the pavement laid over this foundation structure of ballast and ties. No attempt will be made here to more than outline the various methods of construction, as local conditions determine to such a great extent the nature and necessity of the different types of street railway track design.

Proper drainage, of course, is essential and as the ties and ballast invariably extend below the subgrade elevation of the adjoining pavement, the installation of a separate drainage system or one incorporated into the general subgrade drainage system of the street is necessary.

Some street railway systems, particularly those carrying heavy interurban cars, build their entire roadbed structure on a heavy foundation slab of concrete, extending entirely across their trackage area. In others a thick course of broken stone, thoroughly rolled, is used, while others use merely the thoroughly rolled and compacted subgrade. On top of this foundation or subgrade, some traction companies place the ballast of varying depth, thoroughly tamped and compacted, under and about the wooden ties in the same manner as steam railroad track construction. Often this ballast is flushed with a cement grout. Other companies bring their rails to the proper elevation and completely surround the wooden or steel ties with concrete.

It is not good practice, however, to have this concrete built monolithic with the pavement base course. There should be a definite line of demarkation, between the roadway pavement structure and the street railway structure.

All of these methods, each in its proper place, have merit of stability, endurance, length of life and economy of maintenance and yet no single design has such merit that it could be specified for each and every traction line on each and every street that it traverses. Just as in

road and street design, it is poor engineering to specify exactly the same design and strength of construction for every street or every mile of a highway project.

The rail designs and weights are of course subject to great variation in different cities, but with all of the various standards of T-rails, girder rails, grooved rails, etc., it is best practice to plaster the sides, between the head and base of the rail, with a mortar, say one part

CAR TRACK PAVING

Brick lend themselves readily to solving the problem of proper car track paving. With asphalt filler they absorb impact, keep the sub-soil dry, and are easily removed for track repairs.

cement to three or four parts of sand in order to properly support the paving laid next to the rails. A mastic may be substituted for this mortar. Filling this space not only supports the pavement but prevents accumulation of water.

The bedding course of not more than one inch of sand, granulated slag, slag screenings or stone screenings, is then applied, spread and shaped with a template riding on the rails, as is done for the balance of the pavement.

The crown of the pavement between the rails is subject to special design, depending on the height of the head of the rail, the flange depth of the wheels and the clearance of equipment under the car, keeping in mind that snow and ice on the pavement in the winter will considerably reduce this clearance and often interfere with operation

The type of brick and its method of laying likewise have been and still are subject to considerable variation. Some prefer to lay the brick

longitudinally as stretchers adjacent to the rails, for several courses, and sometimes at least to the ends of the ties. This has its advantage in permitting the track to be repaired or ties replaced without disturbing the roadway pavement. Some companies prefer a nose block or special street railway brick with a champferred end that will fit under the head of the rail and provide a groove for the wheel flanges.

Generally speaking the best practice today, and one that can be recommended, is to use the regular paving brick in one of the recognized sizes, laying it in transverse courses, at least between the rails if not outside also, starting and finishing the courses, rolling the brick and completing the pavement in the same manner and under the same specifications provided for the roadway brick pavement structure. Care should be observed, however, to not lay the brick any appreciable distance under the head of the rail on the inside, or allow the brick to project above the outside edge of the rail. Preferably the brick should just meet the head of the rail on the inside and be about one-quarter of an inch below on the outside.

Prior to applying the asphalt filler it is well to oil the surface of the head of the rail to prevent asphalt sticking to it.

The use of the asphalt filler for vitrified brick pavement construction in the street railway area has proven a distinct advantage to traction companies, not only in water-proofing the surface and preventing the damaging flow of water between the rails and pavements into the substructure below, but also in providing a flexible surface that will take care of the vibration and impact without cracking or shattering. The ease with which the pavement may be removed and replaced and the saving in time, together with the fact that the same brick can be used again, are obvious economies.

The asphalt filler is applied in the same manner and under the same specifications as for the roadway pavement and after it is covered with screenings, the pavement is completed and ready for traffic.

CHAPTER XIII

Vitrified Brick Pavements for Hillsides, Bridges and Approaches, Gutters and Parking Strips

Hillside brick, manufactured as specials, should be and usually are specified on grades in excess of five per cent. because of the greater measure of tractive resistance considered essential—tractive resistance not obtainable with most paving materials in general use. This practice is followed in many hilly sections of the country regardless of whatever other type of paving surface is specified up to the point where the grade begins.

The difficulty of obtaining a perfect surface alignment on steep grades with "soft-mix" pavements also contributes to the wide use of hillside brick. The nature of various types of pavements to "roll" on a grade results in a roughened surface, a condition difficult if not impossible to overcome. This is thwarted with a brick surface because the sand bedding course—regardless of imperfections in the base alignment—can be shaped so perfectly and compacted so uniformly that the completed brick surface will present and retain as smooth a surface on the hillside as on the level.

The hillside brick is a special brick of the same quality as other paving brick, but differs from them in that at least one of the edges on the face exposed to traffic is slightly chamferred or grooved. In the pavement this provides a shallow groove which extends entirely across the pavement with each course of brick. The resultant surface not only offers good tractive resistance to rubber-tired vehicles, but what is even more important, for horse-drawn traffic.

These brick serve the same purpose in the paving of bridge approaches which so often are compelled to be on a grade because of the necessity for having the bridge itself at a proper elevation. One of the regular recognized varieties of paving brick is used to surface the bridge floor the same as on the main highway.

The necessity for the free and rapid flow of surface drainage water to the sewer inlets has created a problem in street pavement design of providing a smooth sanitary paving material that will render this service and at the same time not rot or disintegrate after being

HILLSIDE BRICK

The specially manufactured hillside brick usually is specified for grades in excess of five per cent. Because of its special design, a groove runs entirely across the pavement with each course of brick. This greatly increases the tractive resistance, is a benefit to automobile traffic and a necessity for horse drawn traffic.

BRICK GUTTERS AND PARKING STRIPS

This illustrates the value of brick gutters on bituminous paved streets. Surface water quickly flows away before it can damage the bituminous material. Drippings of grease, oil and gasoline from automobiles can do no damage and the brick surface is proof against rutting no matter how hot the day or how long a vehicle may park at the curb.

continually subjected to this accumulated rainfall and street filth that finds its way to the gutter of a city street.

The automobile, parked for long periods at the curb and dripping oil and grease, also has created a new problem that is now being met by the use of vitrified paving brick gutters and parking strips on those streets paved with bituminous materials of various types. With the automobile came the need for some paving material at the curb which would not deteriorate as a result of the oil drippings, and one also that would not soften in the heat of the sun and become rutted under the weight of parked machines.

Vitrified paving brick, because they are not affected by oil, grease, water, or heat, meet the demand for a durable gutter material and many cities in recent years have and are specifying brick gutters from three to five feet wide on all bituminous paved streets.

Such a design derives its economic support from the fact that it adds considerably to the probable life of the bituminous portion of the pavement.

Parking strips in the center of the street present the same problem, and they too are now paved with brick where a bituminous surface is used on the balance of the street.

The method of laying brick gutters and parking strips follows exactly the methods described in previous chapters on brick paving.

CHAPTER XIV

Semi-Monolithic Vitrified Brick Pavements Concrete Base, Cement-Sand Bed, Expansion Joints, Cement Grout Filler

Despite the fact that the vitrified paving brick lends itself admirably to rigid slab construction, it is the recommendation of the National Paving Brick Manufacturers Association that a flexible design be adopted for general application. This is due to a realization on the part of an ever growing number of leading highway engineers that the flexible pavement surface is preferable in the light of present day heavy traffic and that preference for the flexible design will increase as traffic becomes more intense.

Any type of pavement must, in the last analysis, be supported by the natural soil. Constant movements of the soil—movements that cannot be entirely stopped even under the most perfect drainage and ideal climatic conditions—often leave the rigid slab unsupported in many places. At such times and places heavy traffic will produce fractures unless the slab is designed so heavy as to be uneconomical. In addition to this no rigid slab has as yet been developed that will withstand the natural forces of expansion and contraction from heat, cold and moisture without cracking. This cracking causes unsightliness and later disintegration.

A flexible pavement surface, on the other hand, can "come and go" with expansion and contraction without cracking. Also it adjusts itself to upward and downward soil movements without structural damage.

Flexibility in a vitrified brick surface is obtained by the use of a "soft" filler, preferably asphalt. There are rare occasions, however, where peculiar local conditions make a rigid slab advisable, and it is then that the semi-monolithic brick pavement may be used to advantage.

Construction of the semi-monolithic vitrified brick pavement differs from construction of the flexible brick surface in that the joints between the brick are filled with a cement grout, a bedding course of

one part cement and four parts sand is generally used in place of plain sand, and the use of expansion joints becomes a necessity.

The construction of a cement-grout filled pavement is only advised where the base course is of concrete. Successful brick pavements of this type have been built over flexible bases of rolled stone, slag or gravel, but the hazard that must be overcome, of having even the slightest settlement in the base, should always be considered, as this will allow the pavement surface to stand unsupported and in time, under the impact of heavy traffic, cause it to fracture.

The concrete base should be prepared, the cement-sand bedding course distributed, the expansion joints placed and brick, of the lug type, laid and rolled as previously described. After the cement-grout filler is applied, the pavement should be covered with earth or sand and kept moist, not less than four days and the pavement closed to traffic at least fifteen days.

CHAPTER XV

Cement-Sand Bedding Course for Semi-Monolithic Brick Pavement

The major purpose of the bedding course being to permit the brick pavement surface to be brought to a smooth and even contour, by taking up the inequalities in the base and in the individual brick, it is essential, particularly with a cement grouted brick surface, that this bedding material does not shift or move at any time under the vibration resulting from traffic.

With cement-grouted brick pavements of the semi-monolithic type, this bedding material is generally a mixture of cement and sand in the proportion of one to four. Granulated slag, slag screenings, or limestone screenings also are frequently and satisfactorily used because of their lime content, causing them to "set up" thus preventing any shifting.

The same grade of sand is used for this purpose as is used in the fine aggregate for concrete base, namely that passing a one-quarter inch sieve and not containing more than five per cent. by weight of clay or silt.

The cement and sand are mixed and spread dry and thereafter handled in all respects as is plain sand for a bedding course. The finished depth should not exceed one inch or be less than one-half inch.

A template and often a small hand roller are best used to shape the bedding course. Curbs, guide forms, or railway tracks may be used as guides. In cases where the roadway is too wide to permit a template to span the entire distance, the bedding course has to be finished in sections. Scantling laid on the base, may be used as guide rails in such instances.

Care should be taken to see that the bedding material is evenly distributed. It should be thoroughly raked where compacted by dumping. Upon the uniformity of this bedding course depends to a great extent the continued perfect alignment of the brick surface.

A small hand roller can often be used to good advantage to compact the bedding course, and there are occasions when its use should be insisted upon by the engineer particularly when the depth of the

bedding course is variable due to an uneven surface of the base course or when the average depth of the bedding over a given area exceeds one inch. The roller used for this work should be not less than thirty-six inches in diameter, twenty-four inches in width and weigh not less than ten pounds per inch of width.

The bedding course should be struck off at least twice with a template and then rolled if necessary. Depressions existing should be filled in, and the bed again struck off with the template and again rolled. This operation is continued until a perfect alignment is presented.

After being once thoroughly spread and shaped the bed should never be disturbed before laying the brick.

Recommended Specifications Cement-Sand Bed for Semi-Monolithic Brick Pavements

DESCRIPTION: Upon the base as prepared shall be added a cement-sand bedding which shall become an integral part of the base and which shall be included in and constitute a part of the full depth of base as shown on the plans. Bedding shall be composed of one (1) part portland cement and four (4) parts sand. When finally finished the depth of bedding shall not exceed one (1″) nor be less than a one-half (½″) inch.

CEMENT: Portland cement shall conform to the definition and meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials, Serial Designation C 9-21.

SAND: Sand for the bedding shall be clean, all of which shall be uniformly graded and which will pass a one-quarter (¼″) inch sieve.

Sand shall be free from soft friable material, shale or slate, vegetable or other organic matter. It shall not contain clay or silt in excess of five (5) per cent. by weight.

PREMIXING: Cement and sand for the bedding shall be premixed in the proportions specified by hand or by mechanical batch mixer. Mixing shall continue for each batch until the mass is of uniform shade.

SHAPING: Bedding shall be shaped to a true surface parallel with the surface of the finished roadway by means of a template extending the entire width of the roadway, drawn forward upon the curbs or guide-rails. When the width of the roadway precludes the use of a template spanning the entire distance, the bedding shall be shaped in sections, using scantling laid upon the base as guide-rails. The bedding course shall be struck off at least twice with the template. Any depressions developing shall be filled in and the bed again struck off with the template. This operation shall be continued until perfect alignment is presented.

ROLLING: If directed by the engineer, in addition to shaping with a template, the bedding course shall also be compacted with a hand roller. The roller shall be not less than thirty-six (36″) inches in diameter, twenty-four (24″) inches in width and weigh not less than ten (10) pounds per inch of width.

The bedding course shall be struck off with the template and then rolled. Any depressions existing shall be filled in, struck off with the template and again rolled. This operation shall be repeated until perfect alignment is presented.

HAND FINISHING: When the use of the template and guide rails is impracticable in finishing the bedding surface, it shall be shaped to the surface required by hand lutes.

NO DISTURBANCE: The bedding shall not be disturbed after final shaping prior to laying the brick.

CHAPTER XVI

Expansion Joints for Semi-Monolithic Brick Pavements

Expansion joints, sometimes called cushions, are generally of the premolded type although some engineers still prefer the poured joint. Use of these joints is found necessary with brick pavements only where cement grout filler is specified. While the National Paving Brick Manufacturers Association recommends the use of asphalt filler as a general practice, it recognizes that there are times under peculiar local conditions that preference is given the use of grout filler. Because grout filler results in a rigid surface, expansion joints are required to take care of the expansion and contraction under extremes of temperature.

Much has been written and many theories have been advanced by as many authorities as to the spacing and location of both transverse and longitudinal expansion joints. Practice and experience have taught us, however, that the use of transverse expansion joints at regular and frequent intervals was often carried to the extreme and the defects that followed in many pavements built with transverse expansion joints every twenty to forty feet, soon showed that this remedy for expansion and contraction of the surface, was as bad if not worse than the disease.

The best practice today does not definitely specify every place where an expansion joint should be placed, rather leaving it to the common sense judgment of the engineer to place joints at the places where obviously the effect of expansion or contraction under extremes of heat or cold, would be felt.

These places might be enumerated as follows, quoting from the specifications.

"When cement-grout filler is used, an expansion joint of bituminous material shall be placed parallel with and adjacent to the curb line or street-car track, around every obstruction in the surface of the street, transversely across the street at points of change in grade or alignment as directed by the engineer and transversely across the street at the point of curvature of the curb line at all intersecting streets."

Where a prepared joint is specified it should be composed of such combination of bituminous material with inert aggregate that it will remain pliable throughout the range of temperature to which it will be exposed. It should be not less than three-quarters of an inch thick, deep enough to equal the total depth of the brick wearing surface, and bedding course, and of a length convenient for handling. It is laid in the base during or prior to the operation of placing the concrete and between the brick and curb immediately prior to laying the brick surface. Care should be taken that the ends join.

The poured expansion joint, like the premolded, must be of bituminous material which will remain pliable, and must be heated to a

LONGITUDINAL EXPANSION JOINTS

Premoulded bituminous strips are used on monolithic or semi-monolithic pavements to minimize the effects of expansion and contraction. These strips are placed next to the curb and between it and the brick surface.

temperature sufficient to allow it to penetrate to the bottom of the joints and to adhere to the base, brick and curbs. It should be of the same dimensions prescribed above.

Space for the poured joint is provided by laying against each curb, a wooden strip, slightly beveled, wedged, oiled and provided with hooks to facilitate ready removal. This strip should remain in place not less than 24 hours after the base has been laid or the grout filler applied, to give these a chance to become firm.

As soon as the wooden strips are removed the joints should be cleared of any refuse, and immediately be poured full of the bituminous

material. Where there is any settlement they should be repoured until they remain flush with the surface of the pavement.

The practice of using transverse joints in the concrete base has been discontinued, and is not deemed advisable, except at abrupt grade changes or crowned roadway intersections, and adjacent to or around every permanent obstruction projecting through the base.

Recommended Specifications
Premolded Expansion Joint

USE: When cement-grout filler is used, a premolded expansion joint of bituminous material shall be placed parallel with and adjacent to the curb line or street-car track, around every obstruction in the surface of the street, and transversely across the street at points of change in grade or alignment as directed by the engineer and transversely across the street at the point of curvature of the curb line at all intersecting streets.

QUALITY: Expansion joint shall be a bituminous material unaffected by the action of water or street liquids and shall be of such consistency that the penetration registered by a Roberts sharp No. 2 needle under a weight of 200 gm. for one (1) minute at a temperature of 32°F. shall be not less than twenty (20) and when penetrated by a No. 2 needle under 50 gm. for five (5) seconds at a temperature of 115°F., shall be not over 100.

DIMENSIONS: Joint shall be not less than three-quarters (¾") inch in thickness and not less than depth of the brick in width.

PLACING: Expansion joint shall be placed immediately prior to laying the brick wearing surface. It shall be placed with ends of strips closely joined and in such manner that when brick are rolled the top of joint shall be flush with the top of pavement.

CHAPTER XVII

Cement Grout Filler for Semi-Monolithic Brick Pavements

The grout filler is composed of one part portland cement to two parts of sand. The sand should be of clean, sharp grains, or may consist of screenings from hard, durable rock or gravel. Sizes of the grains must be such that all will pass a No. 12 sieve, not more than forty per cent. pass a No. 50 sieve and not more than six per cent. pass a No. 100 sieve. It must be free from soft, friable materials, shale or vegetable matter and should not contain clay in excess of five per cent.

Immediately before applying the filler the sides and ends of the brick must be thoroughly wet by gentle sprinkling. This is necessary to produce a perfect bond.

The grout is generally mixed in a mechanical mixer, a small batch of not more than two cubic feet of cement and sand combined, being placed in the mixer at one time. Enough water is added to produce a mortar of so-called "creamy" consistency that will flow readily to the bottom of the joints without separation of the ingredients. When this proper amount of water is determined, the same quantity shall be added for each mix to produce a grout uniform in consistency for the entire pavement. The mixing must be of such thoroughness and the application of such character that the cement does not float to the top leaving an inferior filler at the bottom of the joints.

The filler is swept into the joints until it is certain that they are completely filled. After the first application has settled, and before the initial hardening has set in, a second application is made. Less water should be used in the second application so that the mix is of a thicker consistency. Rubber edged squeegees operated at an angle with the joints are used to best advantage in thoroughly filling and finishing the joints.

Where grouting stops for the day, or is otherwise interrupted, a metal strip, one-sixteenth of an inch thick should be inserted in the transverse joint of the brick surface and the filling carried up to that point. Filling should be resumed on the other side of the joint and the

CEMENT GROUT FILLER

Sprinkling the brick surface with water before applying the cement grout filler insures adherence of the grout to the brick.

APPLYING GROUT FILLER

The filler issues from the drum into the snout and thence to the pavement. Stiff brooms serve to flush it into and completely fill the joints.

strip be allowed to remain in place until the grouting reaches initial hardening. It should, however, be removed before final hardening.

After sufficient time has elapsed to avoid injury to the filler a protective covering of sand or earth, not less than one inch deep, should be spread on the roadway. This is kept wet and allowed to remain for not less than four days. It is necessary in this type of construction to keep the road closed to traffic for not less than fifteen days after the grouting is completed to permit satisfactory curing.

Recommended Specifications Cement Grout Filler for Semi-Monolithic Brick Pavements

DESCRIPTION: Joints between the brick shall be filled completely with cement-grout composed of one (1) part portland cement to two (2) parts sand.

CEMENT AND WATER: Portland cement shall conform to the definition and meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials, Serial Designation C 9-21.

Water shall be clean, free from oils, acids, alkalies or vegetable matter.

SAND: Sand for cement grout filler shall consist of clean, sharp grains or of screenings from hard and durable rock or gravel.

(a) Sizes of grains shall be such that one hundred (100) per cent. will pass a Number 12 sieve, not more than forty (40) per cent. will pass a Number 50 sieve, not more than six (6) per cent. pass a Number 100 sieve.

(b) Sand shall be free from soft, friable materials, shale or slate and vegetable or other organic matter. It shall not contain clay in excess of five (5) per cent. Individual grains shall not be coated.

SPRINKLING: Sides and ends of the brick in the joints shall be thoroughly wet by gentle sprinkling immediately before the joints are filled.

FILLING THE JOINTS: Filler shall be mixed in and applied from a mechanical batch mixer of a type specially designed for the purpose. The mixer shall be self contained and portable; it shall be of such a construction and operation that the surface of the pavement will not become splashed with oil or water.

The delivery of the mixer shall be such that the cement and sand will not separate in being applied to the joints.

MIXING: A small batch of not more than two (2) cubic feet of cement and sand combined shall be placed in the mixer and sufficient water shall be added while the mixer is in operation to produce the consistency of mortar. When this is thoroughly mixed more water shall be added slowly until the mixture reaches such a consistency that it will flow readily to the bottom of the joints without separation of the ingredients.

APPLYING: Enough filler shall be applied to fill the joints. It shall be swept therein as applied, making certain that the joints are filled completely from top to bottom.

After the first application of filler has settled in the joints, without having reached initial hardening, a second application shall be made in the manner specified for the first except that less water shall be used in mixing, producing a filler of thicker consistency. The filler shall immediately be worked into the joints by means of rubber-edged squeegees which shall be operated at an angle with the joints.

Successive applications of filler shall be made if needed to insure completely filled joints.

CLOSING: Whenever grouting shall cease or be interrupted, the contractor shall provide metal strips one-sixteenth ($\frac{1}{16}$") inch in thickness, six (6") inches deep and three (3) feet in length which shall be inserted in a transverse joint of the brick surface before discontinuing the grouting at any interval, in order that it shall end

in a vertical joint. Strips shall remain in place until grouting reaches initial hardening.

PROTECTING THE SURFACE: After the roadway has been inspected and sufficient time has elapsed to avoid injury to the filler, a protective covering of sand or earth not less than one (1") inch in depth shall be spread on the roadway. This shall be kept wet for not less than four (4) days.

CLOSING TO TRAFFIC: The brick roadway shall be closed to traffic for not less than fifteen (15) days after grouting is completed.

CHAPTER XVIII

Miscellaneous Uses for Vitrified Paving Brick

The quality and character of vitrified paving brick are such that they are particularly adapted for numerous miscellaneous uses outside of the street and highway paving field. Engineers and architects naturally and automatically turn to vitrified brick as differentiated from common brick, to fill their special needs.

The hardness, toughness, imperviousness and smoothness of each unit are qualities not only desired but almost indispensable in many kinds of construction if the best results are to be obtained.

The principal market for vitrified paving brick is, of course, public street and highway paving. The bricks must pass a series of most rigid tests before they may be accepted for this use. Not all brick drawn from the kilns will meet these tests. Some are slightly overburned, some slightly underburned, others may be almost unnoticeably warped. It is these brick, not classed as No. 1 Pavers, that architects and engineers find so satisfactory for other uses. Often, because of their high degree of vitrification, they are preferred to any other artificial product. Also, they do not command the price of the No. 1 Paver.

Specifications for use follow closely the specifications for kindred materials, such as stone, common or face brick or tile. In the construction of factory floors, or drives, garage floors, and private drives and walks, the methods follow those used in street and highway paving, except that the base and subgrade requirements are altered to satisfy light or heavy duty needs. In the case of bridges, buildings, foundations and underground construction, specifications follow, in a general manner, those prescribed for the use of materials of a similar shape, and somewhat kindred nature.

It is appropriate therefore, considering the wide use of vitrified paving brick in branches of construction other than public paving, to include as an appendix to this volume, the information that follows.

Sewer Construction

Vitrified paving brick have always been in demand for use in sewer construction, especially sewer inverts. No. 1 Pavers are most satisfactory for the inverts. Their imperviousness, resistance to acids and

the action of erosion, unusual strength, smoothness and face alignment, insure a durability and freedom of flow that are requisites in this type of construction. In combination with this quality for the invert, a brick slightly warped or irregular from over-heating, but thereby of extra quality in imperviousness, strength and durability, usually is sought for the outside courses of sewers and the upper rim where perfect faces are not a requisite.

Bridges

Vitrified brick, in their resistance to erosion, climatic influences, expansion and contraction, possess a durability and length of life beyond any known artificial product for the construction not only of bridge floors as part of the street or road but of bridge piers, and arches, and in fact, the entire bridge. In the economy of construction, particularly with bridges having a span of forty feet and less, they possess advantages in cost, endurance and factors of safety. Designs may range from simplicity and plainness to the ultimate of artistic taste and beauty. They are, of course, ideal for rustic bridges in parks and private estates.

Basement and Underground Wall Construction

No waterproofing expense need be figured in the specifications when vitrified brick are used for basements and underground wall construction. The well-known impervious character of the material is proof against the annoyances and damage from moisture penetration. Dry walls are insured; so dry that it is possible to store the most delicate goods in basements constructed of this material. Moisture cannot climb the wall or penetrate through it. Brick slightly overburned, and therefore not marketed as No. 1 Pavers, are more than satisfactory for this type of construction.

Warehouses and Cold Storage

The unusual durability, strength and massiveness of vitrified paving brick, coupled with the quality of imperviousness, are the reasons behind the use of this material in the construction of warehouses. They provide a quality in construction that is desirable in this type of building.

Factory and Garage Floors

Factory floors must be indestructible. They must not absorb filth, moisture or grease. They must always offer good tractive resistance in the interests of safety alone. They must be easily cleaned. They must not crack and crumble under heavy loads, or rut where the loads are frequently applied. Where acids are used in manufacture, a floor

VITRIFIED BRICK FACTORY FLOOR

Vitrified paving brick are ideal for paving factory floors. The illustration shows a floor in a foundry where heavy loads and excessive heat are the rule.

FOR PRIVATE DRIVES AND WALKS

Beauty as well as durability is obtained in paving private drives and walks with vitrified paving brick.

FACTORY DRIVES

Vitrified paving brick are widely used in paving factory driveways because of the extreme durability of the material.

RAILROAD PLATFORMS

Durability, freedom from excessive maintenance, ease of traction for baggage trucks as well as non- slipperyness are features of vitrified paving brick used for railroad platforms, driveways to stations and freight yards.

must be able to withstand splashing and spilling without becoming damaged. These are the reasons why vitrified brick are so widely used.

In the case of garages, where oil and grease make many floors slippery, vitrified brick provide a floor easily cleaned and always offer the necessary tractive resistance.

Private Drives and Walks

Long life, low maintenance, and beauty make vitrified paving brick an ideal material for the paving of private drives and walks. The expense of installation is so little compared with the value in their durability that they are widely used for this purpose. They do not become marked with unsightly and damaging cracks. Their beauty and harmonious blending with surroundings are sought in this branch of construction. Architects frequently specify them for their artistic appearance alone.

WALKS IN SUNKEN GARDENS

Here beauty is the first requisite and the rugged, rustic effect produced by vitrified paving brick blends harmoniously with the surroundings and adds to the picture.

Railroad Platforms and Driveways

It is scarcely necessary to refer to the adaptability of vitrified paving brick for railroad platforms and driveways. Railroads having installed platforms and driveways of vitrified brick have not had to remove the same because of any lack of durability in the brick. Use of vitrified paving brick has reduced if not eliminatd a maintenance budget for platform and driveway repairs and has saved the railroads

many thousands of dollars through the avoidance of damage suits arising from accidents due to slippery platforms. Vitrified brick are never "slick," wet or dry.

Architectural Uses

Principally because of their beauty and ruggedness in addition to their durability, architects specify paving brick for dwellings, office buildings, churches and factories. Brick irregular in shape and color usually are demanded because of the artistic effects that the architect so loves to play with.

Paving brick also are found on the farm where they are used for silos, stock yards and feeding floors, cisterns and water tanks, barns, grainery foundations and corn crib pillars.

Many other interesting and practical uses of vitrified paving brick in the construction field might be given in detail ranging from engine beds and tunnel linings to silos and smoke stacks.